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OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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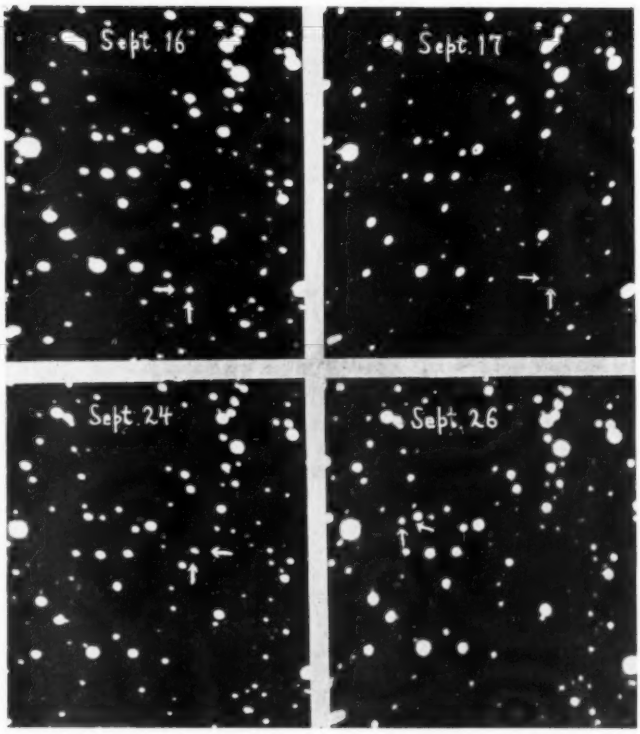
PLATE XVIII.



PHOTOGRAPHS OF HALLEY'S COMET FROM NEGATIVES TAKEN WITH THE TWO-FOOT REFLECTOR OF THE YERKES OBSERVATORY

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VOL. III. SEPTEMBER-OCTOBER, 1909. No. 5

PHOTOGRAPHS OF HALLEY'S COMET*

BY OLIVER J. LEE

THE search for Halley's comet made last winter with the two-foot reflector of the Yerkes Observatory was to be resumed as soon as the field could be reached this autumn. The inference then was that either the comet was not within a degree or two of its computed place or it was fainter than the 17th photographic magnitude,† the latter alternative being preferred. In a recent discussion‡ of his plates taken at Taunton, Massachusetts, Mr. Joel H. Metcalf reaches a similar conclusion.

The full aperture of twenty-four inches was employed for the present photographs, as for the earlier ones. The mirror had been resilvered early this summer by Mr. Parkhurst, which added materially to its light-power. A fresh emulsion of Lumière Sigma plates was used, which, when tested with the Scheiner sector sensitometer, which has been here adapted for the daylight comparison of two plates simultaneously, proved to be faster by one stellar magnitude than the "Seed 27" with which it was compared. It was, moreover, almost free from defects in the

*This article appears in the *Astrophysical Journal* for October. By courtesy of Professor Frost it is supplied this JOURNAL.—ED.

†*Popular Astronomy*, XXVII., 160, 1909.

‡*Ibid*, XXVII., 440, 1909.

film which made very difficult the detection of faint objects on the earlier emulsions of this new brand of plates.

Moonlight and cloudy weather prevented satisfactory exposures upon the field until the night of September 15, four days after the comet had been discovered by Wolf at Königstuhl. It was, however, not until another photograph had been made on the next night that the comet was detected, for the reason that its photographic image on the first plate was partly covered up by that of a faint star, the combination appearing on the plate as a close double.

The original negatives have been enlarged eleven* times in making the reproductions, the scale of which is about 7″·8 per mm. or 3′·3 per inch. The width of each picture is, therefore, 8′. The position predicted from Cowell and Crommelin's elements thus lies within the width of the picture from its observed place. The arrows on the plates indicate the position of the comet, and also the components of its direction of motion. It will be seen that the comet's apparent motion was toward the east and south on September 16 and 17, and toward the west and south on September 24 and 26, retrogression having commenced between the two pairs.

The faintness of the images on September 17 was due to an unfavorable sky.

The bright star shown at the left edge of the pictures is No. 2122 of the Berlin A. G. Catalogue (mag. 8·7), or *B.D.* +17° ·1232 (mag. 8 8), and is the only catalogue star on the part of the plate reproduced. The original negatives, having a much larger field, show a number of catalogue stars.

The comet's positions, as measured on these four negatives, are as follows :

1909	Central Standard Time of Mid-Exposure		Expo-sure	App. α			App. δ		
	h	m	m	h	m	s	°	′	″
Sept. 16	14	45	180	6	18	56	+17	9	23
Sept. 17	14	10	130	6	19	0	17	9	0
Sept. 24	14	27	150	6	18	58	17	6	10
Sept. 26	15	17	60	6	18	44	17	5	20

*By an error of the engraver the reproduction is only 8½ times the original plates.—Ed.

Mr. Parkhurst has derived the photometric reduction-curves necessary for the brand of plates used, preparatory to his photometric researches on the comet. His measures of the approximate magnitude of the comet are :

September 16	Magnitude 16
September 17	Magnitude 16
September 24	Magnitude 15½
September 26	Magnitude 15½

The faintest stars having well-defined images on the negative of September 24 are of magnitude 17 ; these are readily visible on the engraving.

The exposure of 2½ hours on September 24 was made under very good conditions, and a black core runs through the image of the comet. The width of this core, due presumably to the nucleus of the comet, was measured and found to be 3″·5. When the penumbral parts of the image are included, the width of the trail, which may, perhaps, be taken as a rough estimate of the diameter of the comet, is 8″.

YERKES OBSERVATORY,
October 4, 1909

CONVECTION AND STELLAR VARIATION

By Ralph E. DeLury

§1. The object of this paper* is to outline an hypothesis to explain certain general conclusions drawn from the photometric and spectrometric data of variable stars.

§2. It is supposed that the star is a body condensing under the action of gravity and developing great quantities of heat which give rise to rapid radial convection currents bearing masses of hot gases from within and cooler and condensed materials back to the interior, and that, in the absence of disturbing agents, a "kinetic equilibrium" is established, resulting in a steady and practically constant emission of heat and light by the star. Since the radiation from the star depends on the velocity and character of its convection currents, any change in these convections causes a change in the light emitted. Consequently, to account for the variations in the light of some stars, it is assumed that there are changes in the convection currents of the stars caused by the changing action of disturbing agents.

§3. The nature of these convection currents is revealed to some extent by the study of the Sun's atmosphere. Short-exposure photographs of parts of the Sun's surface taken on a large scale at intervals of less than a minute by S. Chevalier† show that the granulation of the photosphere is undergoing very rapid change, and we may attribute this to the rapid radial currents which exist throughout the entire atmosphere of the Sun. The spots, faculæ and prominences, which may be regarded as accentuated developments of the general currents, change continuously, and fre-

*Abstract from a paper given at a meeting of the Royal Astronomical Society of Canada in Ottawa, March 25, 1909, read, by courtesy of Dr. W. F. King, before the Royal Society of Canada, May 19, 1909.

†*Astrophysical Journal*, Vol. XXVII., p. 12-24, 1908.

quently exhibit great velocities in their radial and transversal movements. The number and areas of these disturbed regions vary in a period of average length about 11·2 years, and in about the same period the regions in which the spots are most abundant change in latitude in the north and south hemispheres. It is not yet known whether the convection currents over the entire surface of the Sun vary periodically, but at least the enlarged convections or their results—if we may so term the spots, faculæ and prominences—undergo periodic variations causing changes in the radiation from the regions affected. Now although these changes may not be great enough seriously to modify the total radiation of the Sun, nevertheless in the case of variable stars we may assume that similar changes on a larger scale account for the light-variations.

§4. By thus attributing light-variations to changes in convection currents an explanation is forthcoming for the fact that nearly all continuously variable stars take a longer time in passing from maximum to minimum brightness than from minimum to maximum brightness. This is illustrated in the case of the solar spots,* faculæ and prominences which show a more rapid rise to maximum than fall to minimum. In other words, the accentuated convections in the solar atmosphere rise to a maximum more quickly than they sink to a minimum ; and it is natural to suppose that a disturbance in an atmosphere will be slow to die out completely. If the radial and transversal currents be accelerated in any way they will induce other disturbances. If the ejections of matter be increased the subsequent returns of cooled matter will be greater and there will follow outbursts and further ejections due to the sudden expansions of the cooled materials, and

*Joseph Baxendall in *Monthly Notices*, Vol. XXI. p. 141-142, 1861, discussed Wolf's sun-spot curves and calculated the average value of the ratio, *(Interval from min. to max.)÷(Interval from max. to min.)* or R, to be 0·76 and concluded that "R is least in long periods and periods of greatest activity, and greatest in short periods and periods of diminished activity," and he pointed out the resemblance of the sun-spot curve to the light-curves of variable stars, and supposed that they had a common explanation.

possibly too there will be changes in the phases of matter—solid and liquid to gas—with accompanying electrical effects. Or, the observed effect will be made up of a *primary effect* and an *induced effect* due to the primary effect, *i. e.*,

$$\textit{Observed Effect} = \textit{Primary Effect} + \textit{Induced Effect},$$

or,

$$E = P + I.$$

The nature of the primary and induced effects will, of course, depend on the disturbing action, the length of period and the character of the atmosphere affected. In the case of the Sun it appears that the induced effect, I, is a function of the primary effect, P, involving P to a power higher than the first, since the greater the maximum effect the greater is the fraction of the period spent in the fall away to minimum (foot-note page 345). It is to be expected that the effects produced in gases of low density, such as hydrogen and helium, will differ from those produced in heavy and easily condensed vapors such as iron and calcium, and hence for each element in the atmosphere affected there may be written:

$E_H = P_H + I_H$, for *hydrogen;* $E_{Ca} = P_{Ca} + I_{Ca}$, for *calcium;* and so on. These differing effects are illustrated in the spectro-heliograms taken by Hale, Deslandres, Fox and others. In any variable star the effects for the different elements may or may not be the same, depending on whether or not the elements occupy the same regions affected during the changes.

§5. Changes in the star's convection currents produce variations in luminosity and changes in the character and position of its spectral lines. Variations in brightness may be caused by changes in the quantities of heated matter brought out to the surface of the star, or by changes in the depth and pressure of the absorbing layers in its atmosphere, or by changes in the intensity or position of electrical discharges. Alterations in the character of the spectral lines may be due to these same causes and also to changes in the vapor-density of the elements and compounds. Shifts in the lines of the spectrum may be produced by changes in pressure, a decrease of pressure lessening in general the wave-length,* or by rapid variations in the length of the optical

*Humphreys, *Astrophysical Journal*, Vol. VI. p. 169-232, 1897.

path of the light, brought about either by rapid motions of the luminous masses or by rapid changes in the density of the media through which the light passes, caused either by radial or transversal currents or by sudden changes in the positions of electrical discharges or glows. These latter effects are included in the formula given by Michelson : *

$$N' = N\left(1 - \frac{1}{V}\frac{dL}{dt}\right) = N\left[1 - \frac{1}{V}\Sigma\left(\mu\frac{dl}{dt} + l\frac{d\mu}{dt}\right)\right]$$

where V is the velocity of light in ether, N the vibration-frequency of the line under consideration, N' the observed frequency and L the length of the optical path which is equal to $\Sigma l\mu$, that is, the sum of the optical paths of the various media through which the light passes, l denoting linear distance and μ refractive index referred to ether. It will thus appear that a rapid lessening of the distance away of the source of light from the observer, or of the densities of the media traversed by the light will introduce an increase in the value of N', the observed frequency, and therefore a decrease in the wave-length of the line. This will occur when the convections from the interior of the star are accelerated, the disturbed and, therefore, brighter regions giving character to the spectrum, and at the same time the brightness of the star will increase ; when the convections are most rapid the wave-lengths will be least and the star nearly at its brightest, and as the velocity of the convection currents declines the wave-lengths of the spectral lines increase and the luminosity of the star diminishes. A lessening of pressure will increase the brightness and decrease the wave-lengths simultaneously. Curves representing light-variations and spectral line shifts or changes in wave-length due to atmospheric disturbances in the star will resemble each other in general and agree fairly closely, in point of time, in their maxima and minima : maximum luminosity and minimum wave-length occurring at nearly the same time, as also minimum brightness and maximum wave-length.

§6. Periodicity in the variations of stars has been generally attributed to one of the two periods met with in astronomy,

*Humphreys, *Astrophysical Journal*, Vol. XIII., p. 192-198, 1901.

namely, those of axial rotation and orbital revolution. In the case of sun-spots it has been suggested that the Sun's rotation may, perhaps, introduce periodic changes in its atmosphere, and again that the periodicity may be due to the action of the planets revolving about the Sun in their various periods. The former explanation rests on theoretical considerations,* while the latter hypothesis has some observational evidence in its favor† and it is quite evident that the changing attraction of a satellite would introduce changes of pressure in the atmosphere and even though these changes were slight yet they might be sufficient to cause considerable changes in the established radial and transversal currents. It is conceivable also, that the satellite may establish rotation or accelerate it in the equatorial belt as in the case of the Sun. Let it then be assumed that *the phenomena exhibited by variable stars are caused by changes in their convection currents resulting from the changing action of satellites.* The action of a satellite changes in magnitude and direction when its orbit is eccentric, and in direction only when the orbit is circular. If the satellite revolves in an eccentric orbit the changes in the currents probably do not respond immediately to the increasing attraction of the satellite and do not decrease proportionately with the lessening of the attraction. In other words, it takes an appreciable time for changes in the velocity and character of the convections to become established ; and in addition to this there is the induced effect following each change. This is illustrated in Fig. 1, the dotted line supposedly representing the convection effect and the other curve the tidal effect due to the satellite revolving in an orbit of eccentricity 0·5. If the orbit is circular, changes in the light of the star may be observed since the line of sight is fixed. When the satellite is acting most nearly in the line of sight the star will appear brightest and this condition

* Wilczynski, *Astrophysical Journal*, Vol. VII., p. 124-130, 1898; Moulton, *Ibid*, Vol. XXIX. p. 257-280, 1909.

† Wolf, *Monthly Notices*, Vol. XIX., p. 85-86, 1859; Vol. XXV., p. 216-218, 1865; De La Rue, Stewart and Loewy, *Ibid*, Vol. XXV., p. 104-106 and 115-116, 1865; Vol. XXVI., p. 74-76, 1866; Vol. XXVII., p. 12-14, 1867; Vol. XXIX., p. 141, 1869; Brown, *Ibid*, Vol. LX., p. 599-606, 1900.

being slow to die out the star-light may appear to fall away slowly from maximum in this case also. When the distance of the satellite is comparable in magnitude to the diameter of the star, the two disturbances on the opposite sides of the star will be unequal, and consequently two unequal maxima in the light of the star may be observed, the greater when the satellite is acting towards the observer and the smaller when it is acting away from

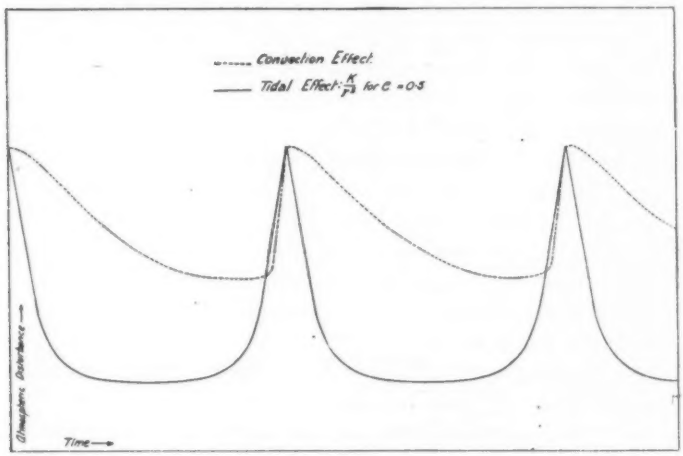


FIG. 1

EFFECT DUE TO A SATELLITE REVOLVING IN AN ORBIT OF ECCENTRICITY 0·5.

him. This may account for the secondary maximum in the light-curves of some variables.

§7. The general results of the investigations of variable stars may be explained by this hypothesis as follows:

(1) *Stars which show symmetrical variation in luminosity are nearly all precise short-period variables of the hydrogen and helium types.* In this case it is assumed that on account of the low density and mobility of hydrogen and helium and of the probably very great depth and rarity of the atmosphere in this type of star its atmospheric changes respond readily to the changing

attraction of the satellite, the induction effect being practically negligible, that is, $E = P + I = P$. Of course there are a great number of short-period symmetrical variables which do not vary continuously and which are, perhaps best explained by the eclipse theory.

(2) *Stars which have asymmetrical or irregular variation are solar-type or red stars*, that is, stars which contain in their atmospheres the vapors of metals and even of chemical compounds as well as the lighter gases. Nearly all the variables of this class spend the greater part of the period decreasing in luminosity, a fact which is explained by assuming that the induction effect is considerable on account of the presence of the vapors of metals and possibly of matter in different phases. There are three distinct divisions in this class: (a) Variables of long period, or "month-variables," that is those whose periods are reckoned in months; (b) Cepheid variables or "day-variables," whose periods are several days; (c) Cluster-variables or "hour variables." whose periods are a few hours. These divisions are represented by the light-curves* shown in Fig. 2. The variables of division (*a*) exhibit irregularities in their periods and in the extent of their variations, while those of divisions (*b*) and (*c*) are very precise in the lengths of their periods and in their light-changes. This is explained by supposing that in the case of the "month-variables" there may be several satellites acting in different periods, or that the changes in attraction are very slow and small so that the fitful disturbances in the atmospheres become more apparent, or that as in the Sun, the spotted or disturbed areas are distributed irregularly in longitude and as the star rotates the light emitted is of irregular intensity, while in the case of the short-period variables there is one close satellite whose attraction changes very rapidly and the changes in convections fall in with a precise oscillation. For the Cepheid or "day-variables" there is a pronounced tendency to a secondary maxi-

* Light-curve (*a*) is from Miss Agnes Clerke's *The System of the Stars;* (*b*) Pickering, *Annals, Harvard College Observatory*, Vol. XLVI., 1903; (*c*) Bailey, *Ibid*, Vol. XXXVIII., 1902.

mum which is not always of the same magnitude ; this may be regarded as a marked induced effect following the maximum primary effect, or it may be explained in the way mentioned at the end of §6.

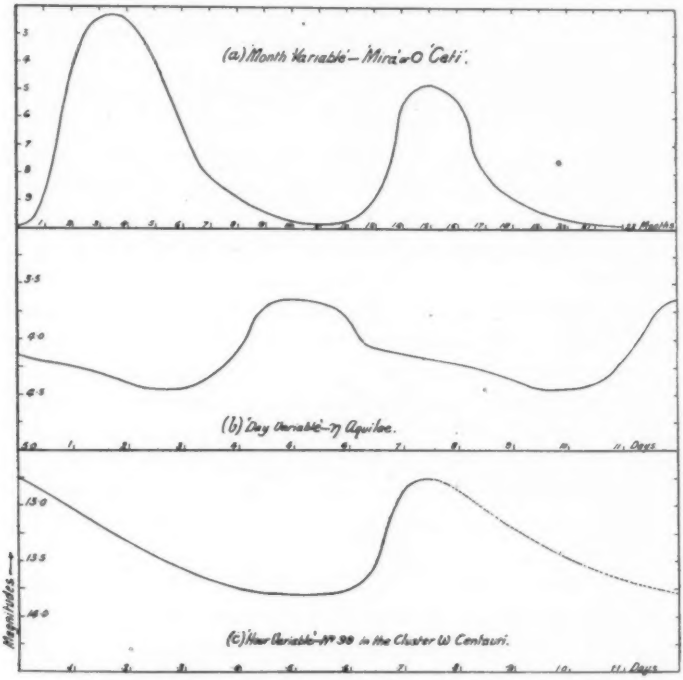


FIG. 2.

LIGHT-CURVES OF STARS HAVING ASYMMETRICAL VARIATION

(3) *Many stars which vary in luminosity show simultaneous changes in the character and position of the lines in their spectra.* If the variation in light is attributed to changes in convections, for reasons already given (§5) it is natural then to assume that there will be simultaneous variations in the character and positions of

the spectral lines, and that possibly some new lines will appear, bright lines for instance, caused by the upheaval of glowing matter above most of the filtering action of the cooler gases of the outer atmosphere, or by changes in the localities of electric discharges. Quite often too the emission and absorption lines of the same element show different displacements, and frequently the lines due to various elements are shifted differently ; phenomena which may be caused by convections of different character in different localities in the star's atmosphere, as illustrated in the case of the Sun. There will, of course, be shifts in the spectral lines due to the velocity of the star as a whole, and in general the "velocity-curves" will be complex, containing the two components due to atmospheric disturbances and to motion of the star. In cases where there are shifts in the lines, all of which agree closely with the assumption of orbital motion of the source of light without accompanying changes in the character of the lines or in the intensity of the light of the star, it is safe to suppose that the shift is entirely due to orbital motion of the star. On the other hand, where there are accompanying variations in the character and intensity of the light, it seems reasonable to assume that the line-shifts are due, entirely or partially, to atmospheric disturbances particularly when these shifts do not agree closely with the assumption of motion of the star in an orbit.

(4) *About a dozen solar-type stars have been investigated which have maximum luminosity very nearly when the spectral lines are of minimum wave-length, while minimum luminosity and greatest wave-length of the spectral lines occur nearly together, the curves of changing light and changing wave-length closely resembling each other.** This class is illustrated by the curves in Fig. 3, which shows the velocity-curve and light-curves of *W. Sagittarii*†

*Albrecht, *Lick Observatory Bulletin*, Vol. IV., No. 138, 1907; *Astrophysical Journal*, Vol. XXV., p. 330-348, 1907; Duncan, *Lick Observatory Bulletin*, Vol. V., No. 151, 1909.

†R. H. Curtiss, *Astrophysical Journal*, Vol. XX., p. 149-181, 1904; Vol. XXII., p. 274-276, 1905.

plotted with the maximum brightness and maximum negative velocity (minimum wave-length) upward, showing the slow falling away to minimum brightness and maximum wave-length which occur simultaneously. An additional curve gives the light-intensities in terms of the light of a tenth-magnitude star. As shown before (§5) this phenomenon can be explained by the changing action of a satellite which affects the velocity of the convection currents thus affecting simultaneously the light of the star and the position of the spectral lines, the lines having maxi-

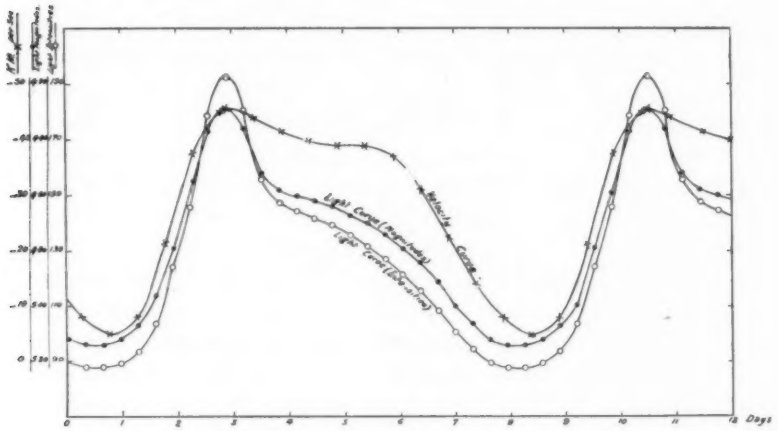


FIG. 3.

LIGHT AND VELOCITY CURVES OF W. SAGITTARII

mum frequency of vibration or minimum wave-length at or near the time of greatest luminosity, the wave-length and luminosity corresponding throughout the period since they are both dependent on the same variable. Nearly all of these stars show the slow falling away from maximum brightness which is presumably due to the induction effect.

(5) *A large proportion of the stars whose periodic spectral-line displacements have been studied show a greater time of increasing*

*than of decreasing wave-length of the spectral lines.** An explanation of some of the cases which constitute this excess over the probable number may be found in the idea of an induced action. That is, let the decrease in wave-length be attributed to increase in the velocity of the atmospheric convection currents, the minimum wave-length corresponding to the maximum velocity of these currents at the period of maximum activity in the atmosphere, and the induced effect following this condition and tending to prolong it as already explained (§4 and §5). There will thus occur a slow falling away to minimum velocity of the convection currents and with it a corresponding slow increase in wave-length of the spectral lines. Thus, if in any of these cases the shifting of the lines is due to atmospheric changes instead of being due as ordinarily supposed to orbital motion of the source of light, the idea of an induced action would explain why it takes longer to pass from the time of minimum to the time of maximum wave-length than it does to pass from maximum to minimum wave-length, that is, why the star is apparently moving longer towards than away from the observer.

§8. There are a considerable number of "spectroscopic binaries" whose periodic variations in light are not great, and yet it is natural to expect changes in luminosity to accompany considerable line-displacements. Possibly the presence of a very deep atmosphere such that the absorbing layers may be disturbed without great disturbance in the emitting layers, may account for this. Or possibly — since the "tidal effect," $\frac{m.\ M}{r^3}$, involves the mass, m, of the revolving star as a direct factor while the orbital velocity,

$$\sqrt{(m + M)\left(\frac{2}{r} - \frac{1}{a}\right)},$$

contains it only as a term in a factor, and, further, since the

*Noted by J. Miller Barr, who gives plausible explanations of the phenomenon in this JOURNAL, Vol. II., p. 70-81, 1908; Vol. III., p. 50-53, 1909. Since the publication of these papers the proportion has been reduced by the study of more cases. The convection hypothesis offers an alternative explanation.

former expression involves as a factor the inverse cube of the distance, r, separating the two bodies while in the latter r is of zero dimension,—the assumption of relatively greater brightness of the revolving star combined with either relatively small mass of the Satellite — m being much smaller than M — or considerable separation of the two bodies, may explain why the line-displacements are appreciable while the variations in brightness are not.

§9. There are also a number of particular cases such as the light-variations and line-displacements of *Novæ* which may be explained by this convection hypothesis.

DOMINION OBSERVATORY,
OTTAWA, CANADA,
May, 1909.

ERRATA

Page 354, third line from the bottom, *instead of* "orbital velocity" *read* "relative velocity."

Page 355, line 2, *instead of* "r is of zero dimensions" *read* "the controlling power of r is $-0{\cdot}5$."

THE ASTRONOMY OF MILTON

By John A. Paterson

THE grandeur of an earthly palace is measured by its distance from east to west and from north to south but the grandeur of a poem is measured by its nearness to heaven. Sublimity of thought and nobility of language are the very embodiment of "Paradise Lost;" the poem is a great poem, and, apart from its theme, the uplift is to the very heaven of heavens, and the outlook is vast as Eternity itself.

> "Three poets in three distant ages born,
> Greece, Italy and England did adorn,
> The first in loftiness of mind surpassed.
> In majesty in both the last,
> The force of nature could no further go,
> To make the third she joined the former two."

and thus blind Milton, shut in "from sight of vernal bloom or summer rose, or flocks or herds or human face divine," sung of "things unattempted yet in prose or rhyme," and made the ages eloquent with that song that swept at large through the compass of the whole universe and through all heaven beyond it, and surveyed all periods of time from before the creation to the consummation of all things. We are not, however, to speak to-night of him as a poet, well called "that mighty arc of song — the divine Milton," but rather of his astronomical knowledge, what he knew of the starry heavens and what purposes he worked out by that knowledge in the exercise of his powers of imagination and description. Young in his "Night Thoughts" says, — "the undevout astronomer is mad," and we might venture to express the correlate of that thought by saying that the devout man who knows not something definite of astronomy is also mad, in that he fails to cultivate as he should those faculties that God gave him, whereby His worship would be advanced. Is it too strong

a statement to make that an average scientist knows a greater and more puissant God than an average Christian? Of an unlettered man it is said,—

> "A primrose by a river's brim,
> A yellow primrose was to him,
> And it was nothing more."

And of a purely scientific botanist it is added,—

> "A primrose by a river's brim,
> Only a *dicotyledon* is to him,
> But that—and nothing more."

Such men see nothing but the shells and husks of things, and know not what the essences of things are.

To many an intelligent man, as it was to Hamlet, (but for another reason), "This brave o'er-hanging firmament, this majestical roof fretted with golden fire is naught but a foul and pestilent congregation of vapors;" but to Milton, as he uplifted his sightless eyes to the firmament, it was not so. To the eye of his soul all was radiant, and in such spirit he breaks forth in that noble apostrophe,—

> "These are thy glorious works, Parent of good,
> Almighty! thine this universal frame,
> Thus wondrous fair: Thyself how wondrous then!
> Unspeakable."

Milton was one of the most, if not the most, deeply read men of his day. His mind was saturated with classics, learned in French, Italian and Hebrew, and in science and philosophy; in general learning he was regarded as the foremost scholar of the University of Cambridge. His travels in Italy, where he met the distinguished literati of the day, gave breadth and polish to his robust intellect. In the opinion of Addison there is an unnecessary ostentation of learning in Milton, while Homer and Virgil exhibited theirs less intrusively. He seemed by his theological excursions into free-will and predestination, and running up the by-paths of astronomy, architecture, geography and mythology, to be anxious to assure his readers that he was acquainted with the whole round of arts and sciences. He uses

technical terms to a fault, such as "larboard" as a seaman would, and encrusts his lines with "doric pillars," pilasters," "cornice," "frieze and architrave," and as an astronomer tells of ecliptic and eccentric, "the trepidation," stars dropping from zenith, rays culminating from the equator — but perfect beauties often have a mole. Nothing in literature can be conceived greater than his description of embattled deities, the Majesty of Messiah, the counsels of the Eternal, the flight of Satan. What can be more terrible than Pandemonium, Sin and Death, as he has them personified? They are as hideous as reptiles crawling in a stagnant pool or weltering in a hideous ooze. And what more beautiful than unfallen Adam and Eve, Paradise, Angels, Heaven? They are as rich garlands of flowers festooned in some noble palace.

When Milton wrote this great poem the basis of astronomical knowledge was shifting. The Almagest of Ptolemy, which taught the geocentric theory had been the text book of science, falsely so called, for more than fourteen centuries. The older Greek astronomers had conceived the heliocentric motions of the planets, but the ingenious Ptolemy had flattered the egotism of man by brushing aside this theory, and explained the motions of the planets and sun and moon by a cumbrous mechanism of cycles and epicycles around the central earth, and as all that corresponded so well with the old legends and myths and had thus become interwoven with the literature and the religion of these centuries, the Ptolemaic system sat enthroned, but on a foundation of clay, which the then Church tried in vain to maintain. Dante had built his Hell, Purgatory and Paradise on some poetic deductions from the theory of Ptolemy. He had put his friends in his ten divisions of Paradise, his critics in his ten divisions of Purgatory and his enemies in his ten divisions of Hell, and who could object to such a convenient use of the Ptolemaic theory? Literature, therefore, maintained it. The common people would accept nothing else, for how could the earth move without throwing everything off? The Church stood by it, for did not Joshua command the Sun to stand still? And, therefore,

the Sun moved and not the earth. Kepler's three laws and Galileo's discoveries shook, but did not overthrow the hoary theory of ages, but not till God said "Let Newton be!" was it completely overthrown and the Almagest cast to the rubbish heap. Students of prehistoric man trace the advancing history of our race by the records of the kitchen middens—the refuse of the food of primeval man, and they lie in *strata* now uncovered. And so we may to-day read the intellectual and scientific history of our race when we lay bare the *strata* of old doctrines and exploded theories, the debris of ages, the middens of old libraries.

Milton lived and thought and wrote in the hot-lit foreground of the controversy. Galileo had been silenced by the strident voice of authority and four years before he died, in the year 1638, when the Italian philosopher was tottering with the weight of seventy-four years, after his imprisonment for the cause of truth, the English poet, a young man of thirty, visited him. Galileo Galilei was even then in his sorrow-stricken old age a prisoner for having taught scientific doctrines which were adjudged heretical. To save his life he had solemnly recanted his error, but as he did he turned from his judges and struck the earth with his foot, and muttered "*Tamen illa movet.*" Two years before Milton saw him he had become totally blind, and thus the inventor of the telescope, the discoverer of Jupiter's satellites which showed a Copernican system in miniature in the sky, was compelled to relinquish his favorite pursuit. His friend, Castelli, writes, "the noblest eye is darkened which nature ever made, an eye so privileged and gifted with such rare qualities that it may with truth be said to have seen more than all of those eyes who are gone, and to have opened the eyes of all who are to come." Galileo endured his affliction with rare fortitude, and thus writes, —"Alas, your dear friend and servant,, Galileo, has become totally blind, so that this heaven, this earth, this universe, which with wonderful observations I had enlarged a hundred and a thousand times beyond the belief of by-gone ages, henceforward for me is shrunk into the narrow sphere which I myself fill in it. So it pleases God, it shall then please me also."

We know not the details of that interview between the astronomer and the poet, who afterwards immortalized his name in heroic verse, and who, in his own old age, suffered as the astronomer did, and to which he alludes so pathetically in these lines,—

> "Thee I revisit safe,
> And feel thy sovran vital lamp; but thou
> Revisit'st not these eyes that roll in vain
> To find thy piercing ray, and find no dawn,
> So thick a drop serene hath quenched their orbs
> Or dim suffusion veiled."
>
> * * * * * *
>
> "nor sometimes forget
> Those other two equalled with me in fate,
> So were I equalled with them in renown,
> Blind Thamyris and blind Maeonides,
> And Tiresias and Phineus, prophets old.
> Then feed on thoughts, that voluntary move
> Harmonious numbers; as the wakeful bird
> Sings darkling and in the shadiest covert hid
> Tunes her nocturnal note."

Milton has not given us any account of this memorable visit, yet it was one which made a lasting impression on his mind and was never afterwards forgotten by him. "There it was," he writes, "I found and visited the famous Galileo grown old, a prisoner of the Inquisition, for thinking in astronomy otherwise than the Franciscan and Dominican licensers thought." Twenty years or more afterwards when Milton, himself grown old and blind, sat down to compose "Paradise Lost" the remembrance of the great Italian rushed to his mind and the great epic embalms his memory in these lines, speaking of Satan's Shield, see,—

Book I., line 286-291,
and Book III., line 588-590,
and Book V., line 261-263.

That was a remarkable meeting of two remarkable men—the great Italian of the same land as Virgil, who wrote the greatest Latin epic, and the Cambridge scholar, who was yet to write the greatest English epic.

Ulyses, that wild rover over land and sea, said, — "I am a part of all that I have met," — and so with Milton — this meeting with Galileo touched his nature. There is a veritable communion of saints on this earth, outside the Apostles Creed, a communion of men devoted to truth, and holy because so devoted. They were apostles of truth these men ; one revealed to us the physical heavens and solved for us the riddle of the universe ; the other lifted us in contemplation to the great Creator's Throne, and we heard the symphonies of creation and learned that though "death came into this world and all our woe" yet a greater Man was foreshadowed "to regain the blissful seat." "Great men," says Carlyle, "are the inspired speaking and acting texts, whereof a chapter is completed from epoch to epoch and by some named history." Galileo was, indeed, an inspired text, read to mankind from the manuscripts of God. Milton too was an inspired text that sang to mankind such rhymes of the universe that all stood enthralled by their melody.

When Milton met Galileo, Copernicus had been dead nearly one hundred years, and yet the Ptolemaic theory, by which it was believed that the earth was the immovable centre of the universe and round it all the heavenly bodies circled in a daily revolution, still retained its ascendency over the men of learning and science. These were the days when the Church taught its own astronomy and biology, and arrogated to herself to dictate theories of cosmogony. She was infallible, and to her was revealed in the written Scriptures all truth, scientific and theological, and woe to the man who declined to accept her teachings. If the eternal scriptures of the sky revealed other teachings which to her propagandists contradicted their narrow views of Holy Scripture, then so much the worse for the unaccommodating teachings of Nature. The Copernican theory, by which the Sun is assigned the central position in our system, with the earth and planets revolving in orbits around him, obtained the support of a few persons of advanced views and high scientific attainments. The new theory had difficulties to surmount. It carried with it some of the errors of Ptolemy. It clung to the theory of

circular orbits, and in order to explain the phenomena it was compelled to keep to some extent to the cumbrous mechanism of cycles and epicycles, until Kepler came and discovered the ellipticity of the planetary orbits. Then, also, it antagonized the cosmogonal theories of the Church, which read Genesis as making the earth the enthroned centre of the starry universe, to whom the great host of heaven paid court. All the traditions of the past presented an embattled front to the new teaching. "What is truth?" said jesting Pilate, while Truth stood before him personified, and truth is always hard to recognize and impossible for some ever to recognize, even if a God reveals her. Milton had read science at Cambridge and afterwards along the lines of current belief, and had assimilated the Ptolemaic beliefs so far as a true soul could assimilate error. His studies in Dante, whom he absorbed, had also fastened on him the Ptolemaic cosmology. According to the Ptolemaic system, the earth, the immovable centre of the Universe was surrounded by ten crystalline spheres or heavens arranged in concentric circles, the larger enclosing the smaller ones, and within these was situated the cosmos or mundane universe, usually described as the "heavens and the earth." To each of the first seven spheres there was attached a heavenly body, which was carried around the earth by the revolution of the crystalline sphere.

First sphere, that of the Moon
Second sphere, that of Mercury
Third sphere, that of Venus
Fourth sphere, that of the Sun (called by Shakespeare, in Troilus and Cressida, "that glorious planet Sol")
Fifth sphere, that of Mars
Sixth sphere, that of Jupiter
Seventh sphere, that of Saturn
Eighth sphere, that of fixed stars,

this was called the firmament as it gave steadiness to the inner spheres. Ptolemy made this last his boundary. He answered the questions which centuries afterwards Young in his "Night Thoughts" asked,—

"Where ends this mighty building? Where begin
The suburbs of Creation? Where the wall
Whose battlements look o'er into the vale
Of none existence! Nothing's strange abode!
Say at what point of space Jehovah dropp'd
His slackened line and laid his balance by,
Made worlds, and measured Infinite no more?"

But after he of Alexandria had settled the Cosmos and pronounced the plan of the great world builder unrolled, some discrepancies and difficulties arose. The precession of the equinoxes, discovered by Hipparchus in the second century, B.C., had to be dealt with as this phenomenon very ungraciously disturbed the harmony and insisted on being explained; and so later astronomers put, so to speak, another story on the building, an extra sphere or two was always at hand, and so they added as an evidence of good faith, and to stop all awkward objections, a ninth sphere, which they called the Crystalline, which accounted for the precession of the equinoxes. Thereafter, in order to demonstrate the inexhaustibility of their resources, a tenth sphere was added, which they called *Primum Mobile* or First Moved, which brought about the alteration of day and night by carrying all the other spheres around the earth once in every twenty-four hours. Thus was evolved the Alphonsine system, as having been adopted and taught by the famous King and Astronomer Alphonso X., of Castile, A.D. 1252-1284. Beyond this last sphere there was believed to exist a boundless chaotic region of immeasurable extent, called the Empyrean, or heaven of heavens, where the Deity was enthroned, the place of eternal mysteries, which was to the mind unfathomable and to the imagination inconceivable. Thus the Cosmogony remained until Copernicus and Kepler and Galileo shook the structure with swift and mighty blows, and Newton with the sledge-hammer force of his great principle of universal gravitation laid it low, and the heliocentric theory took its niche in the temple of Eternal Truth. Since the *Principia*, we have looked upon the law of gravitation as one so well founded that even the gates of hell could not prevail against it, and so did the students of Ptolemy for centuries believe too in

their geocentric theory. Some irregularities in the Moon's motions, some hitches in the eternal fitness of things, have led some deep-thinking scholars to whisper some doubt as to the perfection of Newton's law. Is there to arise some yet greater seer, who will reveal to us some other mystery of dame Nature, and read to this or to some future generation some modification of the law of the inverse square of the distance?

With this statement of the Ptolemaic spheres before us, remembering they are not solid globes but great concentric envelopes, we understand better what is meant by the "music of the spheres" and also Milton's expression in his "Ode to the Nativity," "Ring out ye crystal spheres," and also in the same Ode, where he speaks of meek-eyed Peace coming softly sliding down through the turning sphere. When Shakespeare makes the ghost in Hamlet speak of "stars starting from their spheres" as if in terror, he means these Ptolemaic spheres. Similarly the word "sphere" in our old poetry from Chaucer down has generally this meaning. Indeed, it retains this meaning in many of our current expressions as,— "This is not my sphere," "You are out of your sphere" — not a globe, that would be nonsense, but a great circumference. Our language is often inaccurate; it is traditional. In this case it starts from Ptolemy of Alexandria, and his teaching, who lived and died in the second century after Christ.

When Milton returned to England from the Continent, he lived in London, and undertook the education of his two nephews, John and Edward Phillips, and other sons of his intimate acquaintances. Amongst other subjects of a polite education, he taught Astronomy from a text book "*De Sphæra Mundi*," which was an epitome of Ptolemy's Almagest. This book was written in the thirteenth century and was so popular that it went through forty editions. When Milton taught his pupils the principles of astronomy from it, that text book was four hundred years old. Do you know of any school or university now which has on its curriculum of science books four hundred years old, or indeed, even forty years old, save perhaps, Newton's *Prin-*

cipia, but Newton's *Principia* is sacred, it is the Bible of mathematical truth. This was, however, in the darkness of the middle ages and the lamp of knowledge burned dimly. We shall find that Milton's knowledge of astronomy was comprehensive and accurate. He was familiar with its technicalities and ready with all the arguments in support of the old and the new theory from both scientific and theological points of view. He had a mind which, notwithstanding all his early and later manhood training in the Alphonsine theory, was not shackled by tradition, but was open to the sunbeams of truth. If he had lived in later days, he would have made an intelligent and reverent higher critic both scientifically and theologically. "Custom," says the Chelsea philosopher, "makes dotards of us all" — it made no dotard of John Milton. Most men are too anxious to get truth on their own side, rather than to get themselves on the side of truth. It is pitiful and unprofitable for a man to try and force lovely Truth from her sacred pedestal and to soil her beauty by accommodating herself to lowly and sordid surroundings, but it is a far different thing for a man to rise to the level of truth, and like a true worshipper clasp her sacred knees. Astronomy enters largely into the composition of "Paradise Lost." Indeed, it is difficult to understand how such a poem could have been written without a knowledge of the heavens and celestial orbs and the theory of the Universe. In Book VIII. Milton introduces a scientific discussion between Raphael, the angel, and Adam upon the respective merits of these different theories. The configuration of celestial and terrestrial orbs and the great circles by which they are circumscribed he also knew. The causes which bring about the change of the seasons — the obliquity of the ecliptic — the zodiacal constellations through which the Sun travels and the periods of the year in which he occupies them, are embraced in Milton's knowledge of the science of astronomy. The motions of the earth, including the precession of the equinoxes, the number and distinctive appearances of the planets, their direct and retrograde courses, and their satellites are also described by him. Milton too is familiar with the constellations and their relative

positions, the principal stars, the star groups and clusters and the Galaxy, and in the elaboration of his poem all these bear their part. The names of fourteen of the constellations are mentioned in Paradise Lost, — Andromeda, Aries, Astrea, Centaurus, Cancer, Capricornus, Gemini, Leo, Libra, Ophiuchus, Orion, Scorpio, Taurus and Virgo. Milton in his fourth book introduced a lofty and poetical conception of the means whereby the Almighty made His will known when Gabriel, the warrior angel, discovered Satan in Paradise whispering temptation into the ear of Eve. He thus refers to Libra, (see Book IV., line 995-1005.)

His poet soul recognized Orion, as Job had done centuries before. The rising of Orion was believed to be accompanied by stormy and temptestuous weather, and so we find these lines,—

> "When with fierce winds Orion armed
> Hath vexed the Red Sea coast, whose waves o'erthrew
> Busiris and his Memphian chivalry."

Andromeda is described as being borne by Aries, and in "Ophiuchus huge" Milton locates a comet which extends the whole length of the constellation.

Milton adopted the Ptolemaic theory as the ground work of his cosmogony, not so much from conviction, but because it provided a more convenient working plan for localizing those regions of space, wherein the chief incidents of his poem enter, namely, Heaven or the Empyrean, Chaos, Hell and the Mundane Universe. All space above the Universe newly created and the Primum Mobile was known as Heaven or the Empyrean — a region of light, glory and joy—the dwelling place of the Deity, who, though omnipresent here, was visibly revealed to myriads of angels veiling their faces with their wings and hymning Him throughout Eternity. Underneath there existed a vast illimitable region called Chaos, occupied by embryo elements of matter that with incessant turmoil struggled in battle array,—

> "The womb of nature and perhaps her grave."

The lower portion of this region was divided off, and embraced the locality known as Hell, the place of torment, where the rebellious angels were driven and shut in after their expulsion from Heaven,—

> "As far removed from God and the light of Heaven
> As from the centre thrice to the utmost pole."

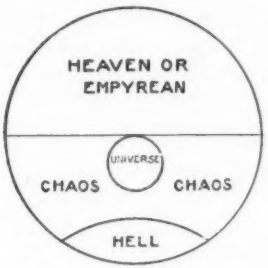


DIAGRAM ILLUSTRATING MILTON'S COSMOGONY

The new universe which included the earth and all the orbs of the firmament, known as the starry heavens, was created out of Chaos and hung as if suspended by a golden chain from the Empyrean above, and although its magnitude and dimensions were inconceiveable, yet, according to the Ptolemaic theory, it was enclosed by the tenth sphere, or Primum Mobile. This is beautifully described as a climax to that magnificent conception of Milton, "The Flight of Satan," who is described as searching through Chaos for the newly created universe. For a while in calm chaotic space, poised on outspread wings, he floats; the sight breaks in on him and there stands revealed

> "Far off the empyreal Heaven extended wide,
> In circuit undetermined square or round,
> With opal towers, and battlements adorned
> Of living sapphire, once his native seat,
> And fast by hanging in a golden chain
> This pendent World, in bigness as a star
> Of smallest magnitude, close by the moon,
> Thither full fraught with mischievous revenge,
> Accurst, and in a cursed hour, he hies."

Care must be taken not to misinterpret this passage for, as the lamented Professor Masson, of Edinburgh University, has pointed out, even Addison is confused by it. He speaks of Satan's distant discovery of the "earth that hung close by the moon" as one of the most wonderfully beautiful and poetical passages of the poem. But it far surpasses Addison's thought, for, as even a correct reading of the passage by itself would have shown, the "pendent World," which Satan here sees, is not the earth at all but the entire starry universe, hung drop-like by a golden touch from the Empyrean above it. "In proportion to this Empyrean at the distance whence Satan gazes, even the starry universe pendent from it is but a star of smallest magnitude seen on the edge of the full or crescent moon."

In his description of the creation the earth is formed first, then the Sun, followed by the Moon and afterwards the stars, all of which are described as being in motion round the earth. In this he closely follows the traditional understanding of the Mosaic cosmogony. Allusion is made to this ancient system in several prominent passages, and in the following lines there is a distinct reference to the various revolving spheres,--

> "They pass the planets seven, and pass the fixed,
> And that Crystalline sphere whose balance weighs
> The trepidation talked, and that first moved."—(Book III., 481.)

The seven planetary spheres are mentioned, then the eighth sphere, that of the fixed stars, then the ninth or Crystalline, which is believed to cause a shaking or trepidation to account for some irregularities in the motion of the stars, and lastly, the tenth sphere or Primum Mobile, called the "First Moved," because it set the other spheres in motion.,

It is much to be doubted if Milton's clear mind with that poetic instinct that discerns truth, ever accepted the Ptolemaic theory, although adopted as a poetic convenience. As if he were watchful of his reputation, and to keep himself right with posterity, we find that he first makes an incidental allusion to the theory of Copernicus in Book IV., 590-8, and further on in the eighth book he introduces a discussion between Adam and

Raphael, and we may, with good reason, take it that Adam's reasoning represented Milton's own view. By a bold poetic liberty he endows Adam, the first of men, (according to the traditional belief) with a prophetic insight which stretched through many future centuries in propounding, as he did, the Copernican cosmogony. Hear Milton argue the case. See Book VIII., 15-38. Note the words "This earth a spot," "Nature, wise and frugal," "Sedentary earth," "Sumless journey."

The angel, after listening to Adam's argument, expresses approval of his desire to obtain knowledge, but answers him dubiously and at the same time criticises in a severe and adverse manner the Ptolemaic theory. (See Book VIII., 66-122.) The angel then lucidly describes the Copernican system in lines,—121-158. Note "Three different motions move," that is daily, annual and the precession of the equinoxes. At this time the law of gravitation was unknown, for it had not yet leaped, Minerva-like, fully armed, from the brain of the Jupiter of natural philosophy, Isaac Newton. Although the elliptical orbits of the planets had been discovered by Kepler, the nature of the motive force which guided and retained them in their paths still remained a mystery. It was believed that the planets were whirled around the sun as if by the action of magnetism, a natural attractive influence having been supposed to exist between them and the orb similar to that of the opposite poles of magnets. Milton alludes to this theory in the following lines,—

> "they, as they move
> Their starry dance, in numbers that compute
> Days, months and years towards his all cheering lamp,
> Turn swift their various motions, or are turned
> By his magnetic beam."

"Magnetic beam" Milton may have builded better than he knew, may have written more wisely than he dreamed. The Sun's "magnetic beam" in the light of our new Astronomy has a meaning past Milton's ken. Milton describes the position of the planets in the sky as

> "Now high, now low, then hid,"

and their motions

"Progressive, retrograde or standing still."

It is evident that Milton was familiar with the apparent irregular paths pursued by the planets when observed from the earth. He knew of their stationary points, and also their backward turnings traced out by them on the surface of the sphere. Galileo imagined he discovered with his telescope on the face of the Moon continents and seas, and that, therefore, the Moon might be the abode of intelligent life, and so Milton (See Book VIII., line 145) presents this possibility. Since then the Moon has been more closely studied, and we have now the theory of the Moon being a ruined world, a burnt out cinder, a derelict in space, acting as the Sun's deputy tide-raiser, and filling the office of a large reflector for the solar lamp, for lovers to swear by and then forswear themselves and by which almanac-mechanics prophesy the wind and rain. One would almost believe that in Milton's day the study of lunar possibilities was in the same condition as is now the study of Martian possibilities. Percival Lowell is supposed to have as conclusively settled to-day the habitability of Mars as Galileo settled the habitability of Luna 300 years ago. Some "mute inglorious Milton" of to-day may loosen his pen and write an epic on Mars, based on the investigations of Flagstaff Observatory, and some cold soulless being in future years may criticise the science of that epic as I am now daring to criticise Milton's line that speaks of

"Rain producing fruits npon her softened soil."

It is possible that we need not wait long for a critic, for has not Dr. A. R. Wallace already spoken in unsympathetic lauguage of the doctrine of planetary habitation? but let me forbear—Milton must not be trifled with.

"and other suns, perhaps,
With their attendant moons thou wilt descry
Communicating male and female light."

Milton in these lines refers to Jupiter and Saturn and their satellites, which had been recently discovered,—four of those of

the former by Galileo, and four of those of the latter by Gassendi. The existence of the male and female light was an idea entertained by the ancients, and which is mentioned by Pliny. The Sun was regarded as a masculine star and the Moon as a feminine, the light emanating from each being similarly distinguished and possessing different properties. Here again may we say Milton wrote nearer the truth than he thought for have we not systems of double suns, physical doubles, flashing out different colors and revolving about a common centre of gravity? In that demonstrated truth lies a close parallel to male and female light. Milton was, no doubt, a Copernican. In the third book he describes the Sun as occupying a supreme position in the system, having the planets with their satellites,—

"That from his lordly eye keep distance due."—(Book III., 578).

circling in majestic orbits round him, acknowledging his controlling powers, and being held by some strong arm that Newton afterwards proved was not only strong but gravitating.

The angel in bringing to a conclusion his conversation with Adam deems it inadvisable to grant him a decisive reply to his inquiry regarding the motions of celestial bodies and in the following line gives a beautifully poetical summary of this elevated and philosophical discussion. (See Book VIII., 150-167). Raphael was, doubtless, a good angel, but he was a bad philosopher. We have read that "fools rush in where angels fear to tread." We are thankful that a chosen band of Adam's descendants in later years — and their names has been legion — declined to take Raphael's advice but had greater courage and "that they did solicit thoughts with matters hid," and that by their laborious investigations they have made for the world a galaxy of truth and held vigorously to the principle that the search for truth is the noblest occupation of man, and its publication a duty. And so wise men walked where Raphael feared to tread,—"Felix qui petit cognoscere causas omnium rerum,"—and in our own humble way, whether we are only plain members of the Royal Astronomical Society of Canada or whether we have become

exalted to the dazzling eminence of being Fellows of the same, let us investigate and reflect. It is not what we are called that counts, but it is what we know and what we do with what we know. "Great truly is the actual" as Carlyle puts it.

But to return to the broad highway. Milton had, like all learned men of his day, some belief in and knowledge of astrology and this he weaves into the theme of his poem. The inauspicious influence of the heavenly bodies is described by him as contributing to the general disarrangement of the happy condition of things that existed before the Fall. He calls Nature to his aid to account for the adverse physical changes that occurred as a consequence of the Fall, and the change of the course of the seasons he explains by a change of the position of the earth's axis, a necessary part of the Copernican theory, in other words the obliquity of the ecliptic. "The poles of earth twice ten degrees and more." (See Book X., 668-679). In the same passage notice the allusion to the Pleiades,—"The Seven Atlantic Sisters"—that beautiful cluster that is believed from time immemorial to have shed happy influences upon the earth, and which, by its close association with human destinies, have been rendered objects of sacred interest among the different races of mankind. There is one other allusion to the Pleiades in "Paradise Lost." In describing the path of the newly created Sun, Milton introduces them as indicative of the joyfulness associated with the birth of the Universe.

> "First in his east the glorious lamp was seen,
> Regent of day, and all the horizon round,
> Invested with bright rays jocund to run
> His longitude through heaven's high road; the gray
> Dawn and the Pleiades before him danced,
> Shedding sweet influence."—(Book VII., 370.375.)

Milton has many beautiful allusions to the starry firmament, as what poet would not? He never appears, however, to have realized the idea that the stars were suns, centres of planetary systems.

In the line quoted above,—

"and other suns, perhaps,
And their attendant moons thou wilt descry,"

I have already observed he does not mean stars, but Jupiter and Saturn with their newly discovered satellites. What impressed him most was their number and brilliancy. The following passages bear witness to his lofty appreciation,—

"About him all the sanctities of heaven
Stood thick as stars."—(Book III., 60-61).

"And sowed with stars the Heavens thick as a field."—(Book VII., 358).

"Amongst innumerable stars, that shone,
Stars distant, but nigh hand seemed other worlds."—(Book III.. 564-5).

Referring to the Moon,—

"her reign,
With thousand lesser lights, dividual holds
With thousand thousand stars that then appeared
Spangling the hemisphere."—(Book VII., 381-4.

The pages of his poem rival the arch of the firmament in glory — gems of literary beauty here — myriads of glowing sapphires there. Many most beautiful allusions to the glories of the Sun and Moon nourish the poetic thought of every student of "Paradise Lost." The poem is a very paradise of poetic imagery, but we cannot stop to gather them; they are like flowers in the meadow—so we hasten. Milton knew the phases of Venus and that sometimes she is a crescent, and so he writes, referring to the Sun as a great source,—

"And hence the morning planet gilds her horns."

Milton introduces several allusions to comets and expresses the ideas of dread that were formerly associated with these objects in his day and in Shakespeare's. In describing the hostile meeting between Satan and Death before the gates of Hell, he writes,—

"on the other side,
Incensed with indignation, Satan stood
Unterrified, and like a comet burned
That fires the length of Ophiuchus huge
In the Arctic sky, and from his horrid hair
Shakes pestilence and war.—(Book II., 706-11)."

Again near the end of the poem when the cherubim descended to take possession of the garden, prior to the removal of Adam and Eve,

> "high in front
> The brandished sword of God before them blazed,
> Fierce as a comet."—(Book XII., 632-6).

Milton was wonderfully happy in his descriptions of ordinary natural phenomena. His felicity of thought and the splendour of his poetic genius transcended all, especially when dealing with the heavenly bodies. No poet has given the world a more beautiful description of evening, and by his allusion to the celestial orbs, has added such finished grace to the picture. (See Book IV., 598-609).

It is a strange coincidence, as a stray piece of contemporary history, that, while in the year 1665, Milton, driven out of London by the plague, was in a country house revising and rewriting his "Paradise Lost," Newton, driven out also by the plague, was, in the same year, 1665, thinking out the theory of gravitation, aroused to inquiry by a well known trivial occurrence in his garden, and was testing his theory by calculating the distance the Moon fell to the earth in one second of time. Thus at the same time and in the same country we have the poet-philosopher Milton dealing with the great problems of creation and eternity and revealing to his fellow-men by the spell of his immortal song the counsels of God from before the beginning, and the mathematical philosopher Newton dealing with the great problems of the universe and revealing also to his fellow-men, in that work of God-given genius, the *Principia*, those eternal, unchangeable and universal methods of God's government in nature, based, as they were, on adamantine truth and read by him from the shining Scriptures of the sky.

Before closing, something must be said of Milton's theory of creation. His was the divine-fiat theory, — "Let there be," — and all things instantaneously were, it was the spectacular method, the traditional theory, taken as the author understood it from

> "That Shepherd, who first taught the chosen seed,
> In the beginning, how the heavens and earth
> Rose out of Chaos."

and it possessed all those elements of majesty that entered into the greatest of great poems, and which most sublimely interpreted a transcendentally sublime theme. Milton died a hundred years before Kant or Laplace had suggested the nebular theory of creation, and although evolution had been slowly working out her results, no Darwin yet had sought to interpret her movements, and no Christian philosopher had arisen to point out the good gifts that the truly wise men of modern time were to lay at the feet of our Christ. Tennyson wrote under the sunlight of a later and clearer science,—

> "This world was once a fluid haze of light,
> Till toward the centre set the starry tides,
> And eddied into suns, that wheeling cast
> The planets."

The muses of Poetry and Urania her sister clasped hands and have in all ages sung to the world the sweet rhymes of mother Nature. But Milton's muse did not as beautifully and as fully interpret the teachings of Urania as Tennyson's muse in the *Princess*. When the divine-fiat theory is propounded, mankind says,—"what effort!" When the creation theory of growing from more to more under a divine Architect is explained, then mankind says,—"What power and also what wisdom!" Ruskin writes,—"Is not the evidence of ease on the very front of all the greatest works in existence? Do they not say plainly to us, not, 'there has been a great effort here,' but, 'a great power here?'"

In conclusion let me say that changes in human ideas and the rapid advance of science have to a large extent thrown the poem into conflict with present day knowledge of the physical universe. Had Milton's Astronomy been more modern and had he clothed its truer principles with that glorious imagery that flowed from him in such "harmonious numbers," would the poem have been more pleasing because more scientific and equally poetic? It is, I think, reasonably clear that if Milton had

adopted the evolutionary theory of creation, we could have had no "Paradise Lost." It would have lost its dramatic power and its dynamic fervour. Satan was to launch into space and descry a completely created world and to visit and tempt and ruin a completely created man. He could not have been depicted as watching through aeons of time a slowly evolving habitable globe, and waiting for millenniums to visit a prehistoric vertebrate growing into completeness, and then to destroy him morally. The first three chapters of Genesis constitute an oriental poem in prose, teaching deep spiritual truths and not unscientific when properly understood, and Milton has made of all that, an occidental poem in blank verse. The world is all the richer and better for this—but no evolutionary theory would have brought forth such an epic. We know now that this mundane universe of ours is not built up like so many concentric shells, that there is no limit or Primum Mobile. We have burst through all that, and we have found no chaos beyond, fenced off on this side by a definite limit. We find what we believe to be chaos within our universe—vast pulps or welters of unformed matter, lying disintegrated, the raw material of new universes, but they are not dead like Milton's Chaos and irresponsive to the thrill and throb of movement and, therefore, of life, but being governed and moved by those laws that pierce the remotest limits of space, are fashioned by the hand of the Divine Architect, according to His eternal plans. Milton's divisions of space are poetic only, but yet they have their own philosophy and teach their own lessons. Is not, after all, our universe a mere drop hung from the Empyrean—Heaven above it and close touching it, an impenetrable gloom all round it, and Hell far beneath it. If Heaven does not closely touch us, then, indeed, we are banished and Paradise is lost, never to be regained. Let life be such that we shall have

> "Earth crammed with heaven,
> And every common bush aflame with God."

NOTE.—The writer desires to express his indebtedness to other writers of and enquirers into Milton's cosmic philosophy. Their names and references have, however, unfortunately been mislaid.

THE SYSTEM OF ε HERCULES

By W. E. Harper

IN a previous paper* I have given the elements of the orbit of this star based on a consideration of twenty-three plates made in 1907 and sixty made in 1908. For sake of completeness a short résumé of that paper will be in order since it has not as yet appeared in print.

This star (R. A. $16^h\ 56^m{\cdot}5$; Decl. $+31°\ 4'$; Phot. Mag. 3 9) was announced as a spectroscopic binary by both the Lick and Yerkes astronomers in 1903. On the three plates secured at the latter Observatory Adams noted evidences of the composite nature of the spectrum. The spectrum is of the hydrogen type classified as VII*a* by Miss Maury. The lines most commonly used were the hydrogen H_β, H_γ, H_δ, the magnesium λ 4481 and calcium K (λ 3933). Others appearing from time to time were the iron lines $\lambda\lambda$ 4549, 4404, 4325, 4308, 4233 and the carbon at λ 4267.

On half a dozen plates there were evidences of duplicity; on the remaining plates, aside from the fact that the lines were in a few cases defined sometimes toward the violet, sometimes towards the red, there were no indications of a second spectrum. The velocities corresponding to the two components were measured on the above plates and indicated for the brighter component a maximum velocity of recession of 64 km. per second and a maximum velocity of approach of 138 km. per second. For the fainter component these figures were 40 and 96. These results should be taken as approximate only, as eight lines on the six plates were all that were used.

The plates that were used in the determination of the orbit were those in which the lines appeared as single and they consti-

* Through the courtesy of Dr. W. F. King, the Director, this paper was given at the meeting of the Royal Society of Canada, May, 1909.

tuted about ninety-five per cent. of the total number. The assumption of a secondary disturbance of one-third the period of the main star greatly improved the agreement between theory and observation. The question as to whether this was due to a disturbing satellite or to some physical cause was left open. The suggestion was made that the peculiar form of the curve might possibly be accounted for by having used for measurement, lines which in reality were blends, but weight was given to the satellite theory by the discovery from some early plates of 1909 that the period was changing. The results were published in a previous note.*

When it was seen that the period was a varying quantity it was decided to secure a number of plates in order that another determination of the elements might be made and the variations obtained. Sixty plates were secured this year, and while the results arrived at are not considered final, yet they go to show that some change is taking place in the elements. The measures of these plates as well as those of 1908 are given in Table I.

In the column headed "Observer" the following abbreviations are used :—

P = Plaskett ; P′ = Parker ; C = Cannon and H = Harper.

For convenience of reference the early observations are attached.

*This JOURNAL, Vol. III., p. 238.

Table I

Summary of Observations

Plate Number	Julian Date	Phase	Vel.	Wt.	Residual	Observer	Remarks
1	2	3	4	5	6	7	8
	1908						
1391	2418010·868	·087	− 28·6	6	− 5	H	
1403	017·904	3·099	− 100·9	6	− 13	H	Hδ − 110· and + 23
1483	045·900	2·930	− 90·7	3	− 6	H	
1494	047 861	·868	+ 38·5	7	+ 8	P	
1511	054 856	3·839	− 37·0	7	+ 2	P	
1531	077·813	2·655	− 74·0	7	− 9	H	
1540	080·767	1·486	+ 6·1	6	+ 1	P′	
1545	082·708	3·527	− 74·0	5	− 9	P	
1547	084·770	1·565	− 28·5	2	− 27	H	
1567	094·813	3·561	− 83·1	3	− 20	P′	
1573	096·747	1·472	− 11·0	6	− 18	P	
1582	098·778	3·503	− 65·6	5	+ 1	P′	
1603	105·774	2·452	− 46·2	4	+ 1	P′	
1625	115·733	·340	− 13·8	5	− 7	P	
1630	117·691	2·298	− 31·0	8	+ 6	P	
1640	119·710	·294	+ 6·1	2	+ 16	H	
1648	120·715	1·299	+ 24·8	6	+ 5	P	
1653	124·676	1·236	+ 20 0	6	− 5	P	
1658	126·680	3·240	− 99·5	·3	− 14	H	
1661	126·820	3·374	− 86·1	5	− 9	P′	
1666	129·730	2·267	− 27·0	7	+ 9	P′	
1675	131·658	·172	− 14·5	6	+ 3	C	
1676	131·688	·202	− 22·2	6	− 5	C	Hδ − 80 and + 70
1682	132·716	1·229	+ 31·2	6	+ 6	H	K − 14 and + 62
1685	133·603	2·122	− 27·9	6	+ 1	C	
1686	133·649	2·162	− 36·0	5	− 4	H	
1693	134·707	3·220	− 108·0	5	− 23	P	All lines defined on [violet
1699	136 679	1·169	+ 26·0	4	− 3	P	
1707	137·737	2·227	− 43·6	8	− 10	H	
1712	138·708	3·198	− 81·1	5	+ 5	C	
1713	138·739	3·229	− 65·8	6	+ 20	H	Hδ − 146 and − 2
1719	139 725	·192	− 13·8	6	+ 3	H	
1720	145·708	2·151	− 23 7	7	+ 8	H	
1723	147·583	·003	− 23·8	9	+ 4	H	
1728	148·722	1·141	+ 23·9	6	− 6	P	
1729	149·707	2·126	− 17·6	8	+ 12	H	
1734	151·716	·112	− 27·8	5	− 6	H	
1737	152 598	·994	+ 34·3	8	+ 1	P	Hδ − 84 and + 58
1738	152·631	1·027	+ 34·7	5	+ 2	P	K − 113 and + 32
1743	152·753	1·149	+ 40·2	4	+ 10	C	
1746	153·712	2·108	− 22·3	3	+ 8	H	
1751	154·653	3.049	− 82·5	5	+ 5	P′	
1757	154·795	3·191	− 94·3	5	− 7	H	
1760	155·701	·074	− 22·1	3	+ 2	P	
1761	159·586	3·958	− 28·6	8	+ 3	P	
1774	161·649	1·998	− 24·0	7	+ 3	P′	
1782	169·701	2.003	− 35·0	7	− 8	P	
1793	173·612	1·890	− 47·8	5	− 25	H	
1818	178·585	2·840	− 92.4	7	− 13	H	

TABLE I.—*Continued*

Plate Number	Julian Date	Phase	Vel.	Wt.	Residual	Observer	Remarks
1	2	3	4	5	6	7	8
	1908						
1838	2418181·660	1·891	− 24·0	7	− 2	C	
1844	182·588	2·819	− 98·9	8	− 21	C	
1853	185·578	1·786	− 6·1	5	+ 11	H	
1866	189·604	1·788	− 20·1	4	− 3	C	
1903	216·550	·570	+ 11·2	4	0	H	
1905	217·516	1·536	+ 21·0	5	+ 20	P′	
1906	217·556	1·576	− 10·0	5	− 8	P′	
1917	220·531	·527	+ 18·1	2	+ 10	P′	
1961	259·440	3·225	− 70·3	4	+ 15	H	
1983	272·422	·113	− 30·9	5	− 9	H	
1993	278·461	2·128	− 30·0	5	+ 1	C	
	1909						
2263	2418346·923	2·191	− 43·5	7	− 10	H	
2264	346·958	2·226	− 39·3	8	− 5	H	
2305	360·899	·073	− 18·2	7	+ 6	C	
2306	360·942	·116	− 16·4	7	+ 6	C	
2327	369·883	1·010	+ 48·0	3	+ 15	C	
2328	369·935	1·062	+ 16·0	2	− 17	C	
2370	379 788	2·868	− 78·0	3	+ 12	P	
2371	379·808	2·888	− 54·3	5	+ 27	P	
2384	381·814	·870	+ 36·4	3	+ 6	H	
2385	381·833	·899	+ 38·4	6	+ 6	H	
2454	397·836	·798	+ 30·0	5	+ 3	C	
2455	397·861	·823	+ 29·8	3	+ 1	C	
2513	420·807	3·652	− 38·0	5	+ 15	P′	
2514	420 833	3·678	− 54·3	6	− 3	P′	
2522	423·813	2·634	− 55·8	5	+ 5	H	
2523	423·849	2·670	− 56·3	6	+ 8	H	
2558	465·666	·229	− 11·9	2	− 1	P	
2568	472·771	3 310	− 69·0	4	+ 12	P′	
2573	473·756	·272	− 11·2	3	0	C	
2587	483·666	2·135	− 46·7	6	− 16	C	
2597	486·650	1·095	+ 27·3	5	− 5	C	
2619	494·644	1·042	+ 34·2	6	+ 1	C	
2635	496·672	3·070	− 94·1	6	− 6	H	
2636	496·725	3·123	− 79·6	7	+ 8	H	
2638	497·612	4·010	− 41·0	5	− 12	C	
2639	497·645	·020	− 29·6	6	− 2	C	
2647	501·666	·018	− 31·5	7·5	− 4	C	Overlooked in grouping
2654	502·591	·943	+ 33·3	5	+ 1	P	
2662	507·619	1·947	− 17·8	7	+ 7	H	
2663	507·663	1·994	− 24·5	7	+ 2	H	
2670	514·611	·892	+ 16 2	3	− 16	P′	
2671	514·654	·935	+ 29·6	5	− 3	P′	
2675	515·618	1·899	− 17·8	7	+ 4	C	
2676	515·648	1·929	− 25·0	8	− 3	C	
2682	516·581	2·862	− 68·3	5	+ 12	P′	
2683	516·612	2·893	− 80·2	5	+ 1	P′	
2688	518·658	·915	+ 20·7	5	− 11	H	
2689	518·708	·965	+ 21·9	5	− 10	H	
2702	521·658	3·915	− 19·0	5	+ 15	H	

TABLE I.—*Continued*

Plate Number	Julian Date	Phase	Vel.	Wt.	Residual	Observer	Remarks
1	2	3	4	5	6	7	8
	1909						
2703	2418521·676	3·933	− 23·3	4	+ 9	H	
2710	522·706	·940	+ 42·1	5	+ 9	C	
2711	522·735	·969	+ 31·2	4	− 2	C	
2715	523·642	1·876	− 26·1	4	− 4	H	
2730	528·756	2·967	− 106·1	3	− 20	P'	Overlooked in grouping
2745	530·616	·803	+ 30·3	4	+ 3	H	
2746	530·660	·847	+ 44·2	5	+ 14	H	
2750	537·690	3·853	− 43·8	6	− 5	C	
2751	537·716	3·879	− 33·6	6	+ 2	C	
2758	539·617	1·757	+ 3·5	4	+ 18	C	
2759	539·651	1·791	− 10·8	5·5	+ 7	C	
2766	545·589	3·705	− 49·0	3·5	0	H	
2767	545·639	3·755	− 35·1	3·5	+ 10	H	
2771	546·615	·708	+ 28·4	6·5	+ 6	C	
2772	546·644	·737	+ 23·1	6	− 1	C	
2777	553·537	3·606	− 65·6	3	− 8	H	
2778	553·589	3·658	− 63·4	5	− 9	H	
2782	558·536	·558	+ 2·8	6	− 7	P	
2783	558·576	·598	+ 9·8	6	− 4	P	
2792	567·583	1·558	− 1·2	5	0	H	
2793	567·606	1·581	+ 0·7	5	+ 4	H	

EARLY MEASURES

Julian Date	Phase	Vel.	Observatory	Remarks
2416235·687	3·290	− 58	Yerkes	
242·718	2·276	− 43	Yerkes	
259·910	3·374	− 70	Lick	Mg. line
262·827	2·268	− 34	Lick	Mg. line
272·664	·034	− 22	Yerkes	
616·680	2·053	− 24*	Lick	Mg. line n. v. g.
558·849	3·987	− 31*	Lick	Mg. line

* Results of last two plates kindly communicated by Director Campbell.

In consequence of the poor quality of the lines for measurement the radial velocities obtained, may in some cases, be in error to the extent of 10 or 15 km. per sec. A rough graph of the individual plates of 1908 and 1909 is shown in Figure 1 and conveys a better idea of the discordancy of the measures than can be given in words. The shaded circles represent the 1908 observations, the plain circles those of 1909, while the triangles represent the early observations of Frost and Campbell.

Since the period is very close to an integral number of days the observations for any epoch will group about four points. For this reason it was decided to combine the plates of the years 1908 and 1909, in order that observations in all phases of the star might be used. For the epoch 1907-08 the period obtained from a least-square solution was 4·0126 days; the 1908-09 obser-

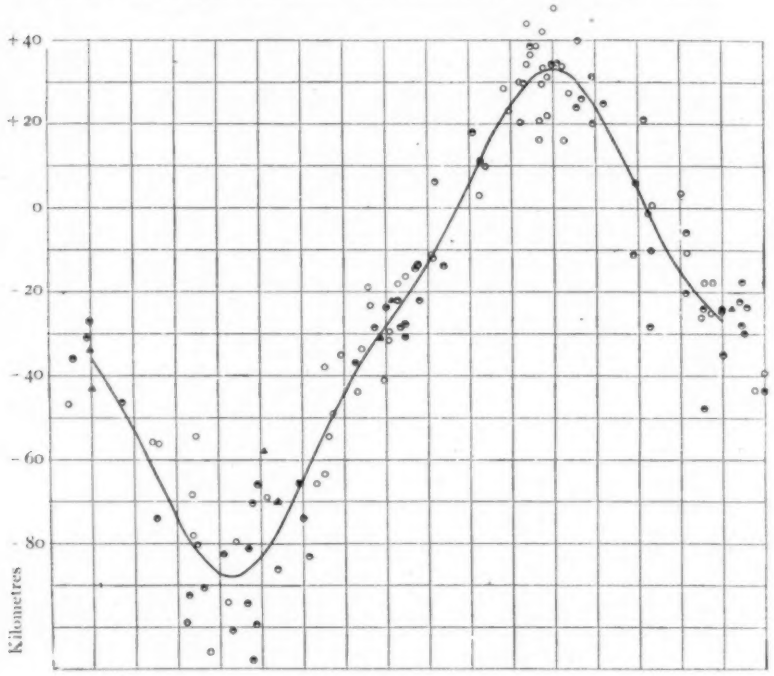


FIG. 1, OBSERVATIONS OF ε HERCULES

vations gave a period of 4·0235 days. This period as it happened suited practically all the early observations, which was not the case when the former period was used.

With this final period the phases of all the observations from an arbitrary epoch were computed. Using as the basis of grouping the phases obtained thereby, the Ottawa observations were

combined into fifteen normal places, none of the plates in a group differing in phase by more than a quarter of a day. Weights were assigned to each group depending not only upon the sum of the weights of the individual plates but also upon the number of nights involved. This grouping is given in Table IV.

It was seen at a glance from the irregular form of the curve that the secondary disturbance was still present though seemingly not so marked as formerly. Preliminary elements, based upon the assumption of its presence, were obtained by the graphical method of Dr. W. F. King.* Many trials were made before arriving at a set of values which seemed to be as close as could be obtained by this method. These preliminary values are given in Table III.

Recourse was now had to the method of least squares which after all is the final method of getting the best orbit from a set of observations. Using the differential form of Lehmann-Filhés,† and adding terms for the secondary, fifteen observation equations were formed connecting the seven unknowns with the computed residuals. The first solution gave such small corrections for the velocity of the system, γ, and the elements K' and T' of the secondary that they were omitted from subsequent solutions. It was thought that the next solution which gave small corrections would have been sufficient, but as a matter of fact two more were required before satisfactory agreement was obtained between the residuals as obtained from the ephemeris and the equation. One would be inclined to think that an error had crept into the second solution, especially as the value pvv lowered so little, but the same result was arrived at from an independent check by Mr. J. B. Cannon, to whom I am indebted also for the measurement of some of the plates.

Table II. following gives the corrections that were obtained from each of the solutions and the resulting value of pvv after these corrections had been applied. The elements from the graphical solution gave a value for pvv of 466.

Astrophysical Journal, Vol. XXVII., p. 125.

†*A. N.*, 3242.

Table II.

Summary of Corrections

Elements	First Solution	Second Solution	Third Solution	Fourth Solution
e	+ ·043	− ·023	+ ·025	+ ·004
ω	+ 56°·503	− 3°·883	− 44°·955	+ 20°·309
K'	+ ·68 km.	− ·63 km.	+ ·66 km.	+ ·04 km.
T'	+ ·621 days	− ·047 days	− ·498 days	+ ·228 days
γ	+ ·06 km.			
K''	+ ·19 km.			
T''	± ·000 days			
$f(m)$	399	·386	296	232

Table III.

Elements of Orbit

Elements		1907-08	1908-09 Graphical	1908-09 Final
Period	P	4·0126* days		4·0235 days
Eccentricity	e	·070	·025	·074
Longitude of apse	ω	191°·65	240°	267°·97
Half amplitude	K'	56·24 km.	52 km.	52·75 km.
Periastron passage	T'	J. D. 2417721·334	... 724·809	2417725·113
Velocity of system	γ	− 29·19 km.	− 27·35 km.	− 27.29 km.
Max. vel. of recession in orbit	A	52·38 km.		52.61
Max. vel. of approach in orbit	B	60.10 km.		52·89
$a \sin i$		3,095,000 km.		2,907,000 km.
Half amplified of secondary	K''	12·26 km.	8· km.	8·19 km.
Time of secondary crossing primary	T'	J. D. 2417727·17[illegible]	... 725·152	2417725·152
$a' \sin i$ (?)		225,000 km.		151,000 km.

*An error in published results gave this as 4·0116 days.

Table IV.

Normal Places

	Phase	Vel.	Wt.	O − C		Phase	Vel.	Wt.	O − C
1	3·895	− 31·68	4	+ 3·91	9	1·881	− 20·29	7	+ 1·88
2	·094	− 23·57	8	− 1·16	10	2·134	− 32·88	9	− 1·74
3	·279	− 8·58	1·5	+ 1·20	11	2·482	− 47·48	4	+ 2·64
4	·632	+ 15·73	3	− ·49	12	2·862	− 82·17	4	− 1·52
5	·894	+ 32·34	7·5	+ 1·13	13	3·157	− 87.14	6	+ ·30
6	1·107	+ 30·56	6·5	− ·74	14	3·346	− 78.50	1	+ ·35
7	1·419	+ 6·63	2	− 4·05	15	3·625	− 58·24	4·5	− 2·03
8	1·563	− 0·82	2·5	+ 1·00					

The above Table III. gives a comparison of the elements according to the determinations. The period is without doubt a varying quantity. The other changes if real might be explained by a direct motion of the line of apsides possibly connected in some way with the secondary disturbance. It is outside the purpose of this paper, however, to deal with this side of the question,

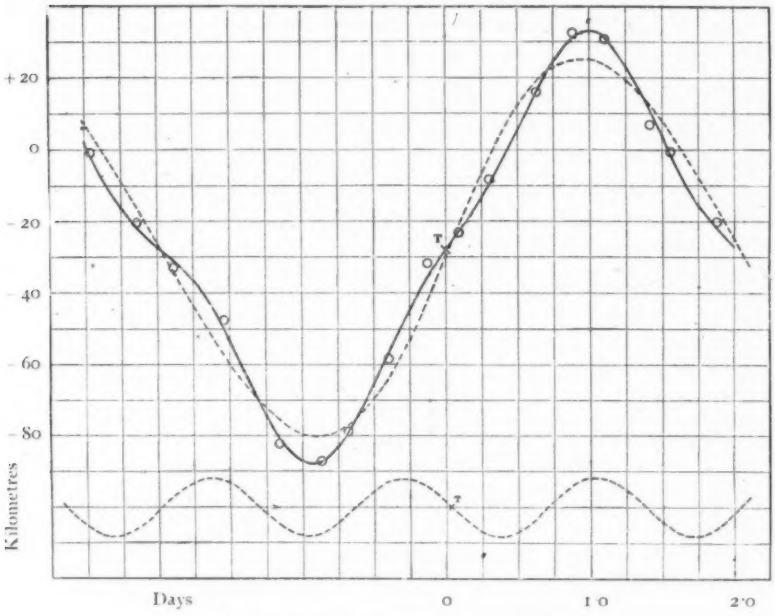


FIG. 2, VELOCITY CURVE OF ε HERCULES

the primary consideration being the best determination of the orbit from the observations.

The probable error of a plate obtained from columns 5 and 6 of Table I. in which the residuals are scaled directly from the curve is ± 6·4 km. per sec. The probable error of a normal place of weight unity is ± 2·7 km. per sec.

The curve, Fig. 2, is plotted from the final elements, the heavy curve being the resultant of the two dotted ones. It seems to agree fairly well with the observations.

I acknowledge with pleasure the advice and encouragement given by the Director, Dr. W. F. King, in the prosecution of this work.

DOMINION ASTRONOMICAL OBSERVATORY
OTTAWA, CANADA,
October 1909.

MEETINGS OF THE SOCIETY

At Toronto

October 9, 1909.—The first meeting of the session was an open one, and by courtesy of the authorities of the University of Toronto, was held in the Chemistry and Mining Building. A good audience was present and Professor Alfred Baker, who occupied the chair, in a few appropriate words introduced the lecturer for the evening, Professor Edwin B. Frost, the Director of the Yerkes Observatory of the University of Chicago.

Professor Frost's subject was "Some Phases of Work in a Modern Observatory," and consisted of a detailed account of the work done by the great institution over which he presides. The Yerkes Observatory was founded by the late Charles T. Yerkes, of Chicago, chiefly through the representations of George E. Hale, and with Professor Hale as Director, began its work in 1897. It is located on the shore of Lake Geneva (in Wisconsin) about seventy-six miles from Chicago. Mr. Yerkes desired that the institution be second to none, and in magnificent buildings, instrumental equipment and scientific production it has risen to that standard.

Professor Frost exhibited photographs of the institution and of the workers there, to whose devotion and enthusiasm he paid the highest compliments. On some occasions the work has been continued the entire night with a temperature 20° below zero, and it was stated that if the sky is clear during any part of the night it is impossible to keep Messrs. Barnard and Burnham in bed.

The monumental work on double-stars by Burnham, especially the preparation of his great *General Catalogue*, which will be the standard for a century, was described. Views of the Bruce photographic telescope with some of the beautiful photographs of comets and star fields, taken by Barnard, were shown on the screen, and illustrations of the work done by the two-foot reflector were also given. The work on variable stars was outlined and then an account of the spectroheliograph, constructed under Hale's directions with examples of its revelations, followed.

Professor Frost then gave a good account of the great spectroscope and of its work. This is the lecturer's special field and some beautiful photographs showing motion of the heavenly bodies were presented. A set of spectrum photographs clearly indicated a course of development in the stars emitting the light which produced them.

In conclusion the lecturer referred to the fact that the spectroscope showed that the multitudes of stars were composed of matter familiar to us on the earth, and it would seem, therefore, that the substance composing the earth and which we deal with here, is the same as the best in the universe.

In eulogistic terms, expressing the pleasure the audience had in the lecture, a vote of thanks was moved by Mr. John A. Paterson, K.C. This was seconded by Prof. C. A. Chant, who remarked that while most lecturers had to obtain slides to illustrate their talks from the various observatories Professor Frost's slides were made under his own direction at the Yerkes Observatory. After further appreciative remarks by Mr. A. F. Miller, the vote was put to the meeting and carried enthusiastically.

October 26.—The following were elected members of the Society.

Miss L. B. Durand, 237 Huron Street, Toronto.
Miss Minnie Johnston, 12 Taylor Street, Toronto.
Miss Marguerite Corner, 109 Pembroke Street, Toronto.
Dr. J. E. Hett, Berlin.

Under the heading of "Predictions" an interesting discussion took place respecting the approaching appearance of Halley's Comet. The comet was first sighted at Heidelberg by Professor Wolf in almost exactly the position predicted for it.

Under "Observations" Mr. R. M. Wallace gave an account of his experiences in making a reflector, and his encouraging success.

Mr. R. S. Muir stated that during the last few months he has been observing Mars and Saturn with the Todhunter telescope, and that he had seen several very fine auroræ.

Mr. A. F. Miller reported his observation of Mars during the late opposition with his 4-inch refractor, describing the appearance of the surface of the planet, and the peculiarities of the markings, comparing his impressions with his earlier observations.

Mr. Elvins spoke upon the subject of some of his early observations of Mars, and regarding the displays of aurora seen within the last few weeks.

Through the kindness of Mr. R. F. Stupart, a diagram was shown of the Observatory record of the magnetic storm of the 25th of September last.

E. A. D.

AT PETERBOROUGH

September 28.—An open air meeting of the Society was held this evening, and a large number of citizens availed themselves of the opportunity of viewing the heavens at close range.

For this purpose two telescopes were placed on the lawn in front of the Collegiate Institute, and for nearly three hours a steady stream of people took their turn at the sights afforded.

The telescopes were in charge of Messrs. Collier and Easson, who pointed out the special features of the planets under observation, and kindly answered the numerous questions asked.

During the early part of the evening the Council for the Centre met and made plans for the ensuing fall and winter, and

the promises of a number of prominent astronomers and public men make the prospects for the season very bright.

October 13.—The following were elected members of the Society,—

John Crane, Manager Dominion Bank, Peterborough.
Edmund L. Goodwill, B.A., B.C.L., LL.B., Peterborough.
Rev. Geo. W. Henderson, B.A., Peterborough.
Wm. F. Johnston, 533 Downie St., Peterborough.

The lecturer of the evening was Mr. G. Parry Jenkins, F.R.A.S., the presiding officer of the Hamilton Centre. Mr. Jenkins is a pleasing speaker, and he was assisted by Mr. H. O. Fisk, who placed on the screen a fine set of lantern views.

In opening his lecture Mr. Jenkins referred to the present polar controversy, and to give an intelligent conception of the conditions in northerly latitudes presented a number of very fine views of the expedition sent by the Canadian Government in 1905 to Labrador to observe the total eclipse of the Sun. The views showed the equipment of the expedition and the eminent astronomers selected by the Government to handle the same. There was proof positive that eminence in scientific work meant "coats off" sometimes, at least, for here were Prof. Maunder, of Greenwich; Dr. King, of Ottawa Observatory; Prof. Chant, Dr. Marsh, Mr. Jenkins and the rest photographed at manual labour.

The Indians of the far north were gratly interested in the equipment of the expedition, but nothing so puzzled them as the fact that the white man was able to make stone. They saw the concrete in its plastic state, and later they were able to inspect the resulting pillar of stone. They were simply astounded.

The subject of the lecture was "Nebulæ and Star Clusters," and in language almost free from technicalities an account of the latest theories as to the formation of the solar system was given.

To the naked eye but two nebulæ are visible, one in the constellation Orion, and one in Andromeda. But the telescope has found up to the present about 120,000 of these great masses in

the heavens. What are they? They are great clouds of gaseous material, which in process of time, condenses, and forms a sun.

Starting with two of the great nebulæ which apparently "are without shape and void" in accordance with Biblical terms, photographs were shown of nebulæ in various degrees of development, their spiral shape apparently indicating that they were in motion, and in some cases had thrown off portions which had formed worlds, and would in time form a "solar system," such as ours. Over 65,000 of the known nebulæ are of this spiral shape, in various stages of transition.

To investigate the nebulæ the spectroscope has also been invoked, and it clearly shows that they are gaseous.

At the conclusion of the lecture, Rev. G. W. Henderson eulogized the speaker on his very able discourse, and noted with pleasure that he had throughout his lecture indicated the hand of God in the workshop of the Almighty, and thus had given testimony to his firm Christian belief. Mr. Henderson, after further commenting on the elevating and educative influence of the address, moved a resolution of thanks, which was seconded by Mr. H. B. Collier.

It was mentioned that Captain Bernier, the Canadian explorer, had promised to address the Centre.

E. F

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

August, 1909

Temperature.—In British Columbia, a nearly normal temperature in the south decreased northwards to the Cariboo District, where there were negative departures of from 3° to 7°. In the Peninsula of Ontario, the Ottawa and St. Lawrence Valleys and throughout the Maritime Provinces the average was just or not quite reached. Elsewhere in the Dominion the average was generally exceeded. Positive departures of from 3° to 5° were recorded from Saskatchewan to northwestern Ontario.

Precipitation. — The precipitation during August varied greatly with the district. In the southern parts of Vancouver Island and the Central Valleys of British Columbia, throughout Alberta, in most districts of Ontario and locally in Quebec and the Maritime Provinces the amount was much less than average, whereas in some of the remaining portions of the Dominion the positive departure was very marked, especially so in the eastern portion of Quebec, the extreme southwestern portion of the Peninsula of Ontario and also in portions of Prince Edward Island.

September, 1909

Temperature.—The mean temperature of September exceeded the normal value over the Southern Mainland of British Columbia, the Prairie and the Maritime Provinces ; elsewhere in Canada the average was not reached.

Many days of unseasonably warm weather occurred in the Prairie Provinces, resulting in a mean temperature of from 4° to 8° above the average.

In Ontario the temperature was subnormal by from 1° to 5°.

Temperatures for August and September

Station	August		September	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson	80	26	69	12
British Columbia				
Atlin	70	34	67	28
Agassiz	87	42	88	35
Barkerville	70	30	66	29
Kamloops	92	44	93	39
New Westminster	80	42	82	37
Port Simpson	68	44	69	41
Vancouver	79	43	78	37
Victoria	76	45	81	38
Western Provinces				
Battleford	98	32	90	25
Broadview	—	—		
Calgary	84	32	84	31
Carman	93	38	87	30
Edmonton	88	30	87	26
Medicine Hat	95	36	92	32
Minnedosa	92	30	88	32
Moosejaw	96	36	89	30
Oak Bank	89	37	82	32
Portage la Prairie	87	44	85	35
Prince Albert	88	38	84	27
Qu'Appelle	86	36	84	26
Regina	92	33	89	25
Swift Current	92	32	89	28
Winnipeg	93	34	85	30
Ontario				
Agincourt			92	38
Aurora	93	35	84	31
Bancroft	91	32	88	29
Barrie	90	40	85	36
Beatrice	84	34	85	32
Birnam	91	42	88	30
Bloomfield	89	42	84	36
Brantford	93	71	89	31
Bruce Mines	90	33	78	31
Chatham	96	45	90	32
Clinton	90	40	88	30
Cottam	94	42	86	35
Cockburn Island	87	36	80	32
East Toronto	96	41	88	37
Gravenhurst	85	33	87	28
Haliburton	90	32	89	29
Hamilton	95	45	88	41
Huntsville	—	—	85	28
Kenora	—	—		
Kinmount	88	32	87	27
Kingston	84	42	78	43
Lakefield	88	42	81	36
London	94	42	90	30
Lucknow	91	39	92	29
Madoc	91	32	86	31
Meaford	88	46		
Midland	90	50	92	40
North Gower	94	34	94	35
Otonabee	90	44	87	36
Ottawa	87	43	82	37
Owen Sound	92	39	92	34
Paris	98	44	94	34
Parry Sound	90	36	88	35
Peterboro'	92	36	89	30
Point Clark				
Port Arthur	85	41	77	31
Port Burwell	84	42	79	34
Port Dover	85	43	84	35
Port Hope	89	39	84	36
Port Stanley	83	44	76	32
Ronville	88	33	85	33
Sarnia	90	48	89	33
Southampton	86	40	91	36
Stonecliffe	86	40	86	34
Stony Creek	97	42	94	36
Stratford	90	40	82	29
Toronto	96	45	89	41
Uxbridge	92	36	88	30
Wallaceburg	—	—	89	30
Welland	93	45	89	40
White River	87	29	74	20
Quebec				
Brome	88	31	80	30
Father Point	76	40	72	32
Montreal	88	46	80	42
Quebec	86	37	78	36
Sherbrooke	87	35	79	32
Maritime Provinces				
Charlottetown	88	46	78	41
Chatham	89	38	79	35
Dalhousie	90	40	75	32
Fredericton	92	35	76	33
Halifax	88	41	79	36
Moncton	90	38	79	32
St. John	82	46	67	43
St. Stephen	92	31	77	31
Summerside	85	39	73	36
Sussex	91	35	75	30
Sydney	88	38	79	36
Yarmouth	76	38	78	38

Precipitation.—The precipitation was in excess of normal from Eastern Ontario to the Maritime Provinces, while from the Ottawa Valley and Middle Ontario westward to the Pacific there was a very general deficiency except in the northern parts of British Columbia near the coast, where the rainfall was heavy. The largest positive departures occurred in New Brunswick where the amount recorded was double the average, and the largest negative in the Western Provinces where the amounts recorded were in nearly all cases less than one inch, and in some but a small fraction of an inch.

Earthquake Records by Milne's Seismograph

TORONTO

R. F. Stupart, Director.

P.T. = Preliminary Tremors, L.W. = Large Waves. Time is Greenwich Civil Mean Time, 0 or 24 H = midnight.

No.	Date 1909	P.T Comm		L.W. Comm.	Max.		End.		Max. Amp	Durat.		Remarks
		h	m		h	m	h	m	mm.	h	m	
866	Aug. 13	21	0· ?		21	36·0	21	51·0	0·25	0	3·0	
867	" 16	7	14·1		7	20·2	8	33·8	1·6	1	19·7	Small and extended.
868	" 18	1	40·3		1	57·4	2	11·8	0·15	0	31·5	Thickening at intervals.
869	" 30	13	13·0		13	22·0	13	32·0	0·25	0	19·0	
870	" 31	12	10·5		12	15·0	12	44·0	1·0	0	33·5	Well defined ; Panama.
871	Sept. 8	17	7·5		17	19·6	18	28·5	0·95	1	21·0	

September 14th Instrument dismounted, preparatory to moving it into new Observatory. Installed on the 30th September.

Vibration of boom 14.9 seconds. 1 mm. = 0″·70

VICTORIA, B. C.

E. B. Reed. Superintendent.

No.	Date 1909	P.T. Comm.		L.W. Comm.	Max.		End		Max. Amp.	Durat.		Remarks
		h	m		h	m	h	m	mm.	h	m	
891	Aug. 12	21	34·1		21	48·1	21	42·5	0·2	0	8·8	
892	" 3	10	45·1				10	50·2	0·05	0	5·1	
893	" 16	7	26 0		7	44·8	8	27·6	0·80	1	1·6	Small and extended.
894	" 18	1	3·7				1	51·9	0·05	0	48·2	Thickening at intervals
895	" 31	11	30·2		12	4·0	12	31·0	0·85	1	0·8	Panama
896	Sept. 8	16	55·6		17	3·2	18	15·5	1·60	1	19·9	Probably Alaska.
897	" 19	20	28·8				20	39·0	0·05	0	10·2	
898	" 22	15	1·6				15	28·8	0·10	0	27·2	

Vibration 15 seconds. 1 mm. = 0″·76.

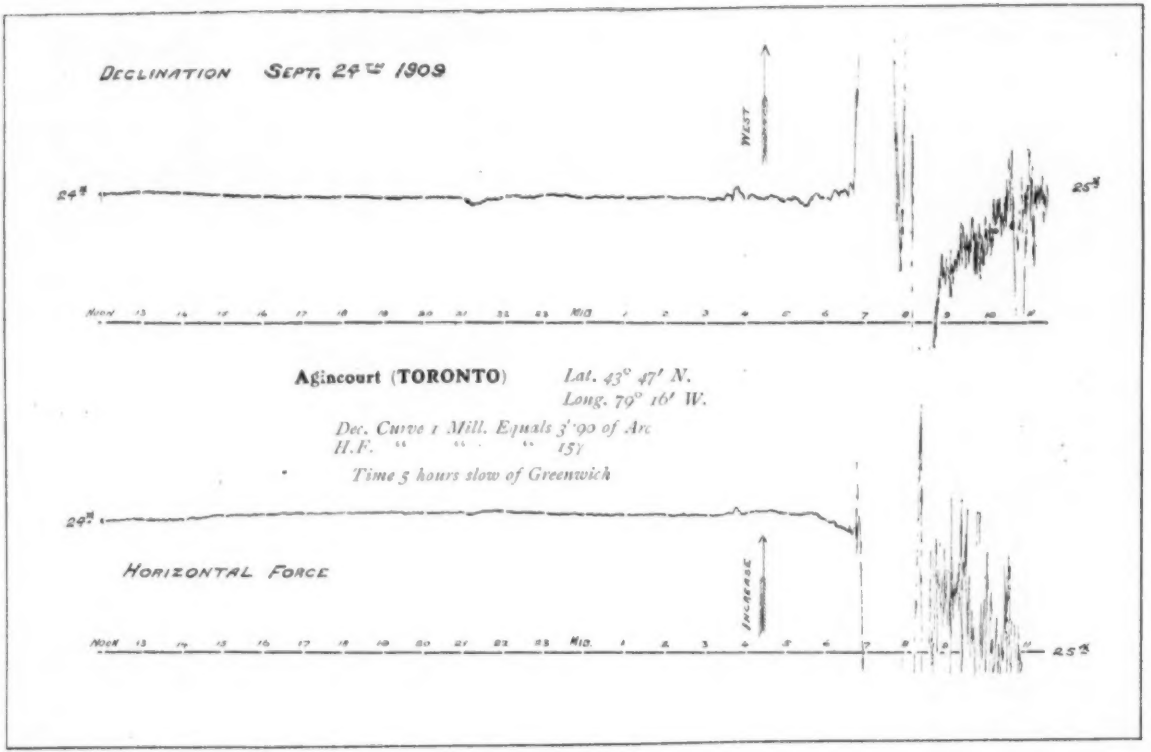
J. Y.

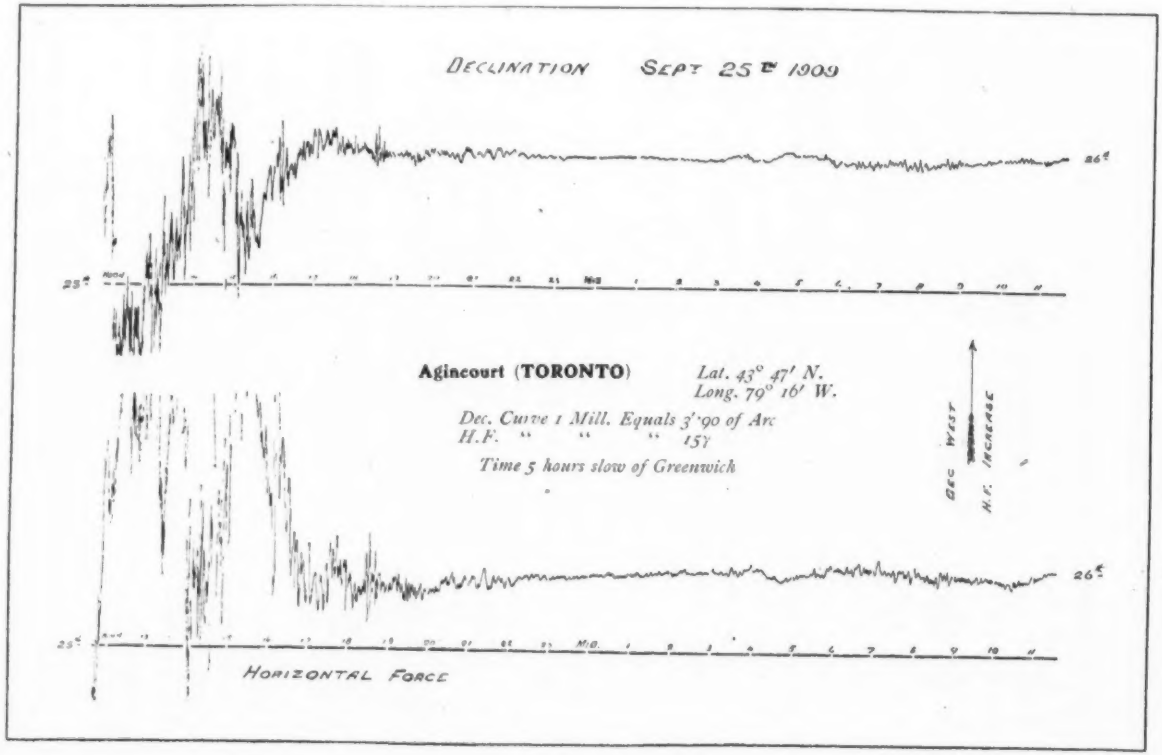
MAGNETIC OBSERVATIONS

On the 25th September there occurred one of the largest magnetic disturbances ever recorded at the Observatory TORONTO-AGINCOURT. In the declination photographic trace, a record at the top of the paper represents a declination 2° 21′ west of the base line value which is 4° 47′6 west and a reading at the bottom of the trace represents a declination 43′ east of the base line, a total amplitude of 3° 4′. Inspection of the diagrams show that while slight disturbance of the declination magnet commenced at $3^h\ 26^m$, the great storm began about $6^h\ 40^m$ with a rapid movement to the westward and within a few minutes the spot of light left the photographic paper and did not return for 53 minutes, when a rapid swing to the east brought the reading at $7\ 48^m$ to within 28′ of the base line.

Another violent movement to the westward when the light again left the paper, was immediately followed by an easterly swing, and the light passed to an unknown distance below the paper. The total range in declination between $6^h\ 40^m$ and $8^h\ 15^m$ certainly exceeding 4° and probably exceeded 5°. The large change in declination and the rapid oscillations of this magnet during the remainder of the day are well shown on the diagram. By 5 p.m. the magnet was quieting down and before midnight was steady in nearly its normal position.

In the bifilar trace a change through the width of the paper represents a change in horizontal force of 738 γ. The storm began at $6^h\ 40^m$ with a sharp increase of force followed in a few minutes by a rapid decrease, when the light disappeared at $6^h\ 55{\cdot}7^m$ and evidently went far beyond the lower limit of the trace. There is some ground for belief that there was a movement in the other direction and return prior to $8^h\ 0^m$ but if so, it was too rapid to leave a record. The light appeared again at $8^h\ 13^m$ with a long swing of the magnet, but soon reversed its movement and from about $8^h\ 30^m$ until noon the force was mostly below normal value, the magnet oscillating through a wide arc. Several large variations above and below normal value with sharp rapid oscillations occurred until nearly $5^h\ 0^m$ when the magnet gradually quieted down. R.F.S.


DECLINATION SEPT. 24TH 1909
WEST
24M
25M
Noon 13 14 15 16 17 18 19 20 21 22 23 Mid. 1 2 3 4 5 6 7 8 9 10 11
Agincourt (TORONTO)
Lat. 43° 47′ N.
Long. 79° 16′ W.
Dec. Curve 1 Mill. Equals 3′·90 of Arc
H.F. " " " 15γ
Time 5 hours slow of Greenwich
24M
HORIZONTAL FORCE
INCREASE
Noon 13 14 15 16 17 18 19 20 21 22 23 Mid. 1 2 3 4 5 6 7 8 9 10 11
25M


DECLINATION SEPT 25TH 1909
Agincourt (TORONTO)
Lat. 43° 47′ N.
Long. 79° 16′ W.
Dec. Curve 1 Mill. Equals 3′·90 of Arc
H.F. " " " 15γ
Time 5 hours slow of Greenwich
DEC WEST
H.F. INCREASE
HORIZONTAL FORCE

ASTRONOMICAL NOTES

In *The Journal of the Franklin Institute*, Vol. CLVIII., No. 3, H. M. Hixon, regarding the earth, remarks :—"Modern science teaches that the atom is not the indivisible or incompressible ultimate that it has been supposed to be, and therefore a gas can have a density greater than its solid form.

If we can prove that any portion of the interior of the earth is above the critical temperature of the matter composing it, we will have proved that it is in a gaseous condition. We know that the elements can be rendered gaseous at the temperature of the electric arc, and we find that the temperature of the electric arc has been determined at from 3500 C. to 4000 C. Now if all these elements can be rendered gaseous in the electric arc, it is strong presumptive evidence that the critical temperature of all known matter is near 4000 C."

The current number of *Popular Astronomy* contains an interesting article, by Owen Ely, on "Theories of Gravitation," in which the author concludes :—

"If gravitation is an action between electrons, our knowledge of it depends on investigation of the dynamics of the electron. If it is electrical in nature, a careful measurement of the electric forces should disclose the source of its energy. Along the least difficult line of research, the testing of weights before and after chemical changes, no reliable data has been obtained to show a loss of weight. C. Zenghelis has shown that the passage of metal vapors through glass accounts for the results of Landolt and others.

These, then, are the main bases of speculation concerning gravitation; an ether pressure, a condensational-rarefactional wave caused by the moving electron, and an electric action be-

tween particles. The last two hypotheses seem more tenable than the first; but owing, perhaps, to the fact that they still remain pure speculation, no one of them has been sufficiently analyzed or developed. No vague explanation nor cloudy description on the part of the theorist should be tolerated. Dynamical reasoning based on available facts may eventually lead to the correct theory; analysis, criticism, and experiment are the means to vertification."

THE ULTIMATE CAUSE OF EARTHQUAKES.—No one should be deceived into concluding that because we seem to have found some evidence of the nature of the process by which the external shell of our planet undergoes its adjustment at the time of an earth shock, we have thereby discovered the *ultimate* cause of earthquakes. That is a far deeper problem, to which the discovery of the *proximate* cause is but an initial stepping stone. It is in this field that the deeper secrets lie hidden. The outlook of the science indicates two lines of effort to be followed up. These are: (1) To make practical application of the knowledge already gained, and (2) to investigate with every possible improvement in method until we have so laid bare the laws of seisms that we may forecast the time, the place and the probable severity of future earthquakes with at least as much accuracy and forewarning as is now possible in weather predictions though it is much to be feared that the science of earthquakes is to pass through a stage not unlike that in meteorology which ushered in the day of scientific prognostication.

POSSIBILITIES OF FUTURE PROGNOTICATION.—It is too early to predict whether more satisfactory bases for future forecasting of earthquakes will be discovered, but the indications are certainly encouraging. Two, and perhaps three, lines of inquiry are already suggested. Most promising of these, is, perhaps, the study of terrestrial magnetism; for in a considerable number of instances, destructive earthquakes have been preceded by periods measuric in hours and sometimes in days, within which the behavior of magnetographs was singularly abnormal. It seems

likely that this change in magnetic conditions may sometimes be utilized as a warning signal. For solution of this problem the completion of the magnetic survey of the world, may be expected to contribute.—W. H. Hobbs, in *Proceedings American Philosophical Society*, No. 192.

Mars in Opposition.—Mars was in opposition at 10 o'clock in the morning of September 24, and since the planet passed through perihelion on August 13, opposition happened not far from perihelion, and it made a rather near approach to the Earth. The eccentricity of the orbit of Mars is 0·093, and at aphelion the distance of the planet from the Sun is more than 154 million miles, whilst at perihelion it is only about 128 million, so that if opposition happened near the latter epoch the Earth is nearer to Mars by about 26 million miles than it is at an opposition which happens when Mars is in aphelion. The heliocentric longitude on August 27, so that when opposition happened at that date the distance separating us from our exterior neighbor was an absolute minimum. In 1892 opposition was on August 3, and the distance between the planets was 35,030,000 miles on August 6. In 1877 opposition was at midnight on September 5, and the nearest approach was 34,983,000 miles on September 4. This year Mars was at it closest on September 18, when its distance from us was 36,155,000 miles. It will be seen that these epochs of close approach happen at intervals of fifteen or seventeen years. —*Observatory*, No. 413.

The Cambridge Observatory is expanding apace. Since Prof. Newall brought the big telescope, there have come the Sheepshanks in one special building, Mr. Cookson's floating zenith in another, the cœlostat house for solar work, and now comes the new dome, with ample computing room attached, for the Huggins telescope. Alongside the growth in buildings there has been an increase in the personnel, so that there are now enough people connected in various ways with the Observatory to form a club which meets in the most friendly way for discussion of astronomical topics.—*Observatory*, No. 413.

IN *The Journal of the British Astronomical Association*, for October, E. M. Antoniadi thus speaks of recent observations of the planet Mars—"The most characteristic feature of the present apparition was, and still is to a large extent, the extreme faintness of the great majority of the dusky areas, which made *Mare Sirenum*, for instance, appear immensely darker than such markings as the *Syrtis Major* and *Sinus Sabæus*. Nothing similar had, of course, ever been seen during the past apparitions of the planet. What, however, struck the Director, at the first glance thrown on Mars in August, was also the fact that *the planet did not appear with its usual ruddy colour, but was pale yellow;* and this yellowness was immediately considered as intimately associated with, or an agent of, the faintness of the *Maria*. That this view was correct became evident between August 23 and 27. On those nights Mars presented to us the *Maria Sirenum* and *Cimmerium* regions, and the contrast between the normal ruddy ground in which details were swarming N. of *Mare Sirenum* and the dull yellowness N. of *Mare Cimmerium*, where such dark spots as *Cyclops*, *Cerberus*, and *Trivium Charontis* were virtually invisible was too obvious to be missed by an observer who had closely studied Mars for ten successive apparitions.

With regard to the nature of these abnormal appearances two theories force themselves upon us: either (*a*) that the *Maria* were discolored, or (*b*) that the markings were obliterated by cloud. Now, the former assumption is hampered by the necessity of supposing that at the same time when the dusky parts were being modified in tint (and seasonal change is rather unlikely in the tropical zone), a similar process of discoloration had also attacked the continental regions, which is scarcely likely. But the cloud theory is capable of explaining all the above facts in the simplest possible manner. However, by the word "cloud" the Director would imagine only the lightest possible cirrus formation, or the thinnest conceivable haze, the diffusive effect of these condensations scarcely equalling the glare of our cloudless blue skies. Such a screen would render paler the dark

spots, and it would appear of a light yellow*—just as has been observed—over the continental regions, as transmitting and blurring the color of the ochre surface beyond, while the shadow it would cast on the planet would certainly interfere with its appearing too bright near the limb.

THE FUTURE OF ASTRONOMY.—It is claimed by astronomers that their science is not only the oldest, but that it is the most highly developed of the sciences. Indeed it should be so, since no other science has ever received such support from royalty, from the state and from the private individual. However this may be, there is no doubt that in recent years astronomers have had granted to them greater opportunities for carrying on large pieces of work than have been entrusted to men in any other department of pure science. One might expect that the practical results of a science like physics would appeal to the man who has made a vast fortune through some of its applications. The telephone, the electric transmission of power, wireless telegraphy and the submarine cable are instances of immense financial returns derived from the most abstruse principles of physics. Yet there are scarcely any physical laboratories devoted to research, and endowed with independent funds for this object, except those supported by the government. The endowment of astronomical observatories devoted to research, and not including that given for teaching, is estimated to amount to half a million dollars annually. Several of the larger observatories have an annual income of fifty thousand dollars.

The practical value of astronomy in the past is easily established. Without it, international commerce on a large scale would have been impossible. Without the aid of astronomy, accurate boundaries of large tracts of land could not have been defined and standard time would have been impossible. The work of the early astronomers was eminently practical, and appealed at once to every one. This work has now been finished. We can compute the positions of the stars for years, almost for

*With remarkable acuteness, Prof. W. H. Pickering came to the conclusion, in 1905, that the clouds of Mars would be yellow (Flammarion, *Mars*, Vol. II., p. 491).

centuries, with all the accuracy needed for navigation, for determining time or for approximate boundaries of countries. The investigations now in progress at the greatest observatories have little, if any, value in dollars and cents. They appeal, however, to the far higher sense, the desire of the intellectual human being to determine the laws of nature, the construction of the material universe, and the properties of the heavenly bodies of which those known to exist far out-number those that can be seen.

The next great advance, perhaps, will be a method of determining the distance of the stars. Many of us are working on this problem, the solution of which may come to some one any day. The present field is a wide one, the prospects are now very bright, and we may look forward to as great an advance in the twentieth century, as in the nineteenth.—PROF. EDWARD C. PICKERING, in *Popular Science Monthly*, No. 8, 1909.

HALLEY'S COMET was observed at the Dominion Observatory, Ottawa, by R. M. Motherwell, on the night of November 10th, with the 15-inch telescope. The comet will probably be visible to the naked eye in January.

ω' PEGASI.—A dispatch from Kiel, through Harvard College Observatory, calls attention to the variable star ω' Pegasi, now at maximum, which deserves investigation for bright lines. Photographs of the spectrum of this variable, taken in 1892, 1897, 1899, 1905 and 1908 with the Draper telescope, at Harvard, show that the spectrum has bright lines, and resembles that of o Ceti. Additional photographs will be taken on the next clear evening. The character of the spectrum, from observations by Mrs. Fleming, was published in *Harvard Annals*, No. 55.

RELATION OF PROPER MOTION TO MAGNITUDE.—In Part I., Vol. XII., *Washburn Observatory Publications*, Professor Comstock commenting on the proper motion of faint stars observed there from 1902-7, remarks,—"If the motions are real, the fainter stars, being presumably more remote, should on the whole present smaller proper motions than do the bright ones, while no such relation should be found if the observed values of μ are in great part the result of accumulated errors. In the table

. . . the progressive diminution of the total proper motion with diminishing brightness is clearly shown . . . I conclude that the proper motions here determined are genuine and, relating to stars fainter than any hitherto investigated for proper motion, they substantially extend the material available for an interpretation of the stellar system."

METEOR OBSERVED IN DAYLIGHT.—A splendid meteor was seen in daylight on October 6 last at $9^h\ 33^m$ a.m. Many persons were surprised to see a silver-like globe of fire sail across the firmament. Near Northampton it gave a loud detonation, windows rattled, and people ran out of their houses in alarm thinking that an earthquake had occurred.

It was seen from Gloucester, Somerset, Sussex, Surrey, Northampton, Hants and other counties, but the observations are more of a general than detailed character. The meteor, however, must have been directed from a radiant in the eastern part of Leo, or in Coma Berenices or Virgo, and its height at extinction was probably about 30 miles over the N.W. border of Northamptonshire. It passed over the region of Herts, Bucks, and Bedford, but exact deductions are scarcely permissible from the available materials. —W. F. DENNING, *Observatory*, No. 415. J.R.C.

THE WONDER STAR. (MIRA).

Now brightly in the southern skies,
Between Aquarius and the Hunter's feet,
Above where earth and heaven in shadows meet,
Mira the star of ancient mystery lies.
And while we gaze in eloquent surprise,
Her bright but transient splendors, all too fleet
Fade from our vision and no more we greet
The wonder star with eager, earnest eyes.

O, Star of Wonder, thy elusive light,
A fitting emblem of all human fame,
Burns with meridian beauty on our sight,
Then fades to dreams of splendor and a name.
Thus for a day man's glory gleams afar,
Then dims to darkness like the wonder star.

A. D. WATSON.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

QUERIES

1. Kindly explain in non-technical language, what is meant by "Lunar Perturbation," *e. g.* in deducing star velocity?

2. How is it that, during an eclipse of the moon, when totality is reached, the moon is still seen, glowing with a dull light?

3. Is the calculation correct that *Arcturus* is travelling towards us at *about* the rate of 4,300,000 miles per day, and that, at that rate, it would take *about* 120,000 years for him to reach us?—BEGINNER.

ANSWERS

1. In determining the velocity of a star in the line of sight, measurement of the spectrum plates gives the velocity with respect to the earth at the time of the observation. To obtain the velocity relative to the Sun we must make three corrections: (1) For the rotation of the earth on its axis, (2) For the revolution of the earth about the common centre of gravity of the earth and Moon, (3) For the revolution of the earth about the Sun. The second correction is the only one in which the Moon appears, though I have not heard it referred to as a "perturbation." Further, its greatest velocity is about $\frac{1}{100}$ kilometre per second and so it is usually neglected.

2. The red hue was long a phenomenon for which no explanation could be found; by some it was considered to be due to a light naturally inherent to the Moon's surface, but Kepler was the first to offer a more scientific explanation. He showed that the phenomenon was a direct result of the refraction of the earth's atmosphere, which had the effect of turning the course of the solar rays passing through it, causing them to fall upon the Moon even when the earth was actually interposed between them

and the Sun. That the color of the Moon's surface is red is due to the fact that the blue rays of light are absorbed in passing through the terrestrial atmosphere, in the same manner as the western sky is frequently seen to assume a ruddy hue when illuminated in the evening by the solar rays.—Chambers' *Handbook of Astronomy*, 4th Edition, Vol. I., p. 328.

3. The distance of Arcturus is so great that it is extremely difficult to measure it. The best determination (Elkin's) gives the distance as 8,700,000 times that of the earth from the Sun, or 140 light years. Viewed from Arcturus, the orbit of the earth would appear no larger than would a circle one foot in radius when seen from a distance of 1,630 miles. Its proper motion is 2″·3 per annum, which, at the distance given, means a velocity of 257 miles per second in a direction at right angles to the line joining the earth to Arcturus. Its velocity in that line is approximately 4·6 kilometres, or 2·1 miles per second towards us. This is equivalent to 181,440 miles per day, but to reach us it would require 913,045 years.

ANSWERS AT AN EXAMINATION

A light year is one in which not many stars are discovered.

A light year is the light received from a star in a year.

The Moon was new on May 29th, 1889, and so on the 31st it was a crescent but two days old. The great Johnstown flood occurred on the latter date, but I suppose one should hardly be surprised to see in a spectacular representation of the great catastrophe at a summer resort, the *Full Moon* rise up over the hills just after midnight. C. A. C.

PREDICTIONS FOR NOVEMBER AND DECEMBER

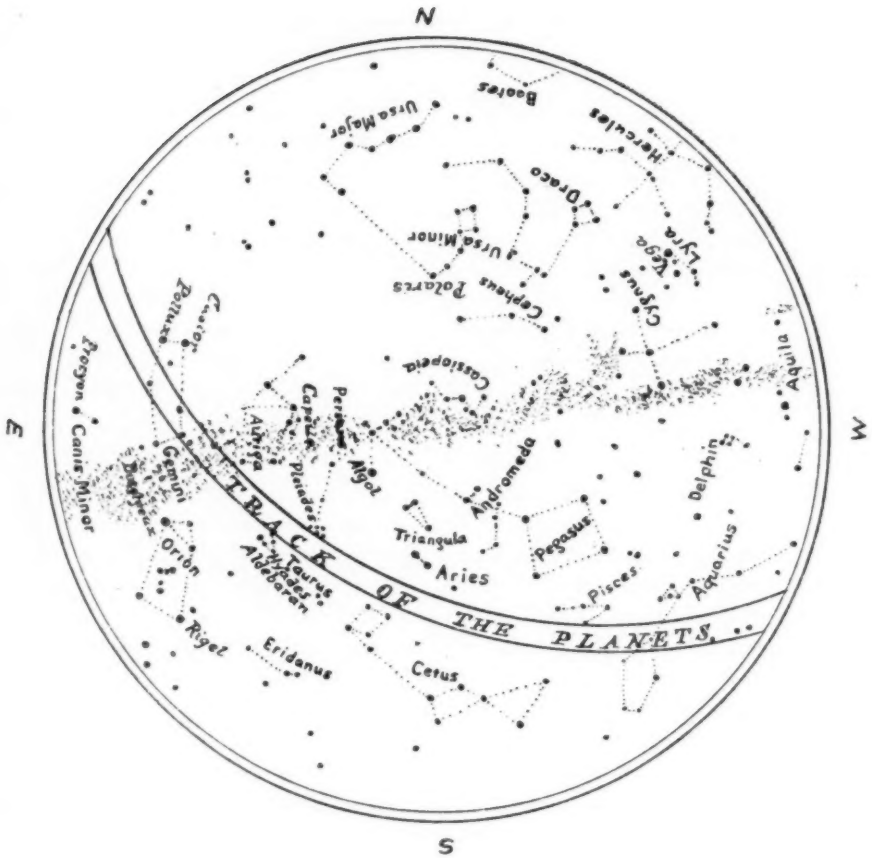
PREPARED BY R. M. STEWART

Constellations on the Meridan in November

Cassiopeia, one of the two bright circumpolar constellations, is named from a queen of Grecian mythology ; it is also sometimes known by the name of *The Lady in her Chair*. During November it is on the meridan, directly above the pole and opposite the Dipper, about nine o'clock ; it is very easily recognized by five bright stars arranged in a zigzag figure like a wide inverted W, which in certain positions is said to resemble the outline of a chair. Lying, as it does, in the galaxy, it contains many fine telescopic fields,

Andromeda lies directly to the south of Cassiopeia, and passes the meridian slightly south of the zenith. Its brightest star, Alpherat, passes meridian at the same time as the most westerly of the five bright stars in Cassiopeia. β, once known by the name, (now entirely out of use), of Mirach Mizar, passes the meridian an hour after Alpherat and about 7° nearer to the zenith. One of the most interesting features of this constellation is the Great Nebula, the only one visible to the unaided eye, which may be located by prolonging the line joining β and μ to its own length beyond μ.

Pegasus, the winged horse of Grecian mythology, lies immediately to the south-west of Andromeda ; three bright stars in it form with Alpherat, in Adromeda, a large and conspicuous figure known as the Square of Pegasus, each side of the square being about 14° in length. The boundaries of the constellation extend a considerable distance to the west and south-west, taking in the bright star ϵ, which lies west and a little south of the star in the right hand lower corner of the square.



THE CONSTELLATIONS ON DECEMBER 1, AT 9 P.M.

Pisces, (The Fishes) lies to the southeast and east of Pegasus and south of Andromeda. It is the twelfth sign and the first constellation of the Zodiac; although it contains quite a large number of stars, none of them are brighter than the fourth magnitude, and it is a quite inconspicuous constellation. It is occupied by the Sun from March 15 to April 16.

Cetus, (The Whale) is a fairly large constellation lying to the southeast of Pisces. It contains two stars, α and β, of the second magnitude, and eight of the third. β may be identified by prolonging the eastern side of the Square of Pegasus about two and a half times its own length to the south; α lies about 40° towards the northeast. About one-third of the way from α to β, in a direct line between them, lies Mira (The Wonderful). It is a variable star, having a period of about eleven months; at its maximum brilliancy it is somewhat brighter than the second magnitude, though it does not attain this degree of brightness in every period; its minimum is about the ninth magnitude; the last maximum occurred about the end of September last.

Constellations on the Meridian in December

Aries, (The Ram), the first sign and second constellation of the Zodiac, lies immediately to the north-east of Pisces. Its brightest star α, otherwise known as Hamal, is of the second magnitude; it is situated directly east from the centre of the Square of Pegasus, at a distance of about double the diameter of the latter; near it to the south-west, is β, of the third magnitude; the constellation contains no other stars brighter than the fifth magnitude.

Triangulum((The Triangle), is a small constellation marked by a right-angled triangle of three stars of the third magnitudes The centre of the triangle lies about ten degrees directly north of Hamal.

Perseus,, named after a hero of Grecian mythology, lies to the east of Andromeda and north-east of Aries. Its brightest star, α, is known by the name of Mirfak; it is of the second

magnitude, and crosses the meridian slightly north of the zenith at nine o'clock (local time) on December 26. About ten degrees a little west of south from it is Algol (The Demon), the best known variable star in the heavens. Ordinarily it is of the second magnitude, but once in every period of two days and nearly twenty-one hours it is partially eclipsed by a companion which revolves around it ; the eclipse occupies eight or ten hours, during about half an hour of which it is only of the fourth magnitude. It is easily located by noting that it is a little less than half way from the Pleiades to Cassiopeia. Another interesting feature of this constellation is the double cluster, lying about half way between Mirfak and Cassiopeia, which is referred to in another part of these Predictions.

Mercury

During the greater part of November and December Mercury is unfavorably situated for observation ; it is a morning star until December 3, when it is in conjunction with the Sun ; after that an evening star. At the beginning of November it rises about an hour and a half before the Sun, somewhat to the north; at the end of December it sets about an hour after sundown, in the same spot as the Sun. It is in conjunction with Uranus on December 28, and with the Moon on November 11 and December 13.

Venus

Venus will reach its greatest elongation at noon on December 2, when it will be 47° 18′ to the eastward of the Sun ; at that time it will set about three and a quarter hours later than the Sun. It will steadily increase in brightness during the whole of November and December, reaching nearly its greatest brilliancy by the end of the year. On November 17 it will be in conjunction with the second magnitude star σ Sagittarii, passing nearly half a degree, or almost the apparent diameter of the Moon, above the latter. It is in conjunction with the Moon on November 16 and December 16, and with Uranus on November 23, Uranus being about two and a half degrees to the north.

Mars

Though its distance from the earth is now considerably increased, Mars is still one of the most conspicuous objects in the evening sky. During these two months it will undergo a marked diminution in brightness, its distance at the end of December being over two and a half times that at opposition in September. Its motion is 19° to the east and 11° to the north. It will be in conjunction with the Moon on November 22 and December 20, and with Saturn on December 21.

Jupiter

Jupiter, which is now well to the west of the Sun, will be a morning star during November and December; on December 1 it rises at 2 a.m. During these two months it moves 8½° to the east and nearly 5° to the south; on account, however, of the eastward motion of the Sun, its distance from the latter continually increases. It is in conjunction with the Moon on November, 9 and December 6,

Saturn

Saturn remains favorably situated for observation throughout November and December. It continues to retrograde until December 20, on which date it again begins to move slowly to the eastward. On December 31 it is overtaken by Mars, which has been approaching it since the latter part of October, and passes it rather more than three degrees to the north. It is in conjunction with the Moon on November 22 and December 21.

Some Interesting Doubles Visible in Small Telescopes

σ *Cassiopeiæ*. R. A. $23^h\ 54{\cdot}4^m$; Dec. 55° 15′; magnitudes 5·4, 7·5; distance 3″; colors white and blue.

35 *Piscium*. R. A. $0^h\ 10{\cdot}3^m$; Dec. 8° 19′; magnitudes 6·2, 7·8; distance 11″·5; colors white and purplish.

38 *Piscium*. R. A. $0^h\ 12{\cdot}7^m$; Dec. 8° 22′; magnitudes 7, 8; distances 4″·7; colors yellow and white.

η Cassiopeiæ. R. A. $0^h\ 43{\cdot}6^m$; Dec. 57° 20′; magnitudes 4, 7·6; distance 9″·7; colors yellow and purple; binary with period 222½ years; large proper motion, 1″·2; distance from Sun 22 light-years.

36 *Andromedæ*. R. A. $0^h\ 50{\cdot}1^m$; Dec. 23° 8′; magnitudes 6, 7; distance 1″; strong yellow color; probably a binary.

Polaris. R. A. $1^h\ 26{\cdot}5^m$; Dec. 88° 49′; magnitudes 2, 9; distance 19″; distant from Sun at least 40 light-years.

γ Arietis. R. A. $1^h\ 48{\cdot}4^m$; Dec. 18° 51′; magnitudes 4·2, 4·4; distance 8″·6; a pretty object,

α Piscium. R. A. $1^h\ 57{\cdot}3^m$; Dec. 2° 19′; magnitudes 3, 4; distance 3″·5; good contrast in colars, but colors troublesome to define; probably a binary.

γ Andromedæ. R. A. $1^h\ 58\ 3^m$; Dec. 41° 54′; magnitudes 3, 5; distance 10″; colors yellow and blue-green; one of the finest doubles; the smaller star itself a very close binary.

ι Trianguli. R. A. $2^h\ 7{\cdot}1^m$; Dec. 29° 53′; magnitudes 5, 7; distance 3″·5; colors yellow and blue; very fine.

ι Cassiopeiæ. R. A. $2^h\ 21{\cdot}6^m$; Dec. 67° 0′; magnitudes 4·2, 7·1, 8·1; distances 1″·9, 7″·6; colors yellow, blue, blue; the close pair is probably a binary; all three have a common proper motion.

θ Persei. R. A. $2^h\ 38{\cdot}0^m$; Dec. 48° 51′; magnitudes 4·2, 10, 9; distances 16″, 68″; colors yellow, violet, grey; the two closer stars have a large common proper motion, and probably form a binary system.

γ Ceti. R. A. $2^h\ 38{\cdot}6^m$; Dec. 2° 51′; magnitudes 3, 6·8; distance 2″·6; colors pale yellow and blue; common proper motion; probably a very slow binary.

Radiant Points of Meteor Showers

Date	R. A. h	R. A. m	Dec. °	
November 1	2	52	22	Near ϵ Arietis
November 2	3	40	9	Near ϵ Tauri
November 12-14	10	00	23½	The Leonids; near ζ Leonis
November 13-18	10	16	41	Near μ Ursæ Majoris
November 19-23	4	08	23	The Taurids; near ν Tauri
November 27	1	44	44	The Andromedes (Biela's Comet); near γ Andromedæ
Nov. 30-Dec. 4	12	56	43	Near α Canum Venaticorum
December 4	7	20	25	Near δ Geminorum
December 6	5	20	23	Near ζ Tauri
December 8	9	35	8	Near o Leonis
December 10	7	22	33	The Geminids; near α Geminorum
December 22	12	56	67	Near 8 Draconis

Meridian Passage of the Principal Planets During November and December

LOCAL MEAN TIME

	For November 15		For December 15
Mercury	11.05 A.M.	Virgo, Libra, Scorpio, Ophiuchus, Sagittarius	12.25 P.M.
Venus	3.04 P.M.	Ophiuchus, Sagittarius, Capricornus	3.16 P.M.
Mars	8.19 P.M.	Pisces	7.00 P.M.
Jupiter	8.51 A.M.	Virgo	7.10 A.M.
Saturn	9.30 P.M.	Pisces	7.28 P.M.
Uranus	3.42 P.M.	Sagittarius	1.50 P.M.
Neptune	3.47 A.M.	Gemini	1.47 A.M.

Clusters and Nebulæ

H.IV.18. R. A. $23^h\ 21{\cdot}5^m$; Dec. 42° 2′; small but bright nebula of annular or spiral structure.

H.VI.30. R. A. $23^h\ 52{\cdot}5^m$; Dec. 56° 12′; a beautiful large faint cloud of minute stars, magnitudes 11 to 18; rather a condensed patch in the Galaxy than a separate cluster.

H.V.18. R. A. $0^h\ 35{\cdot}4^m$; Dec. 41° 11′; a large faint oval nebula; best seen with a low power; resolvable; a very large field includes it with *M*.31 and *M*.32.

*M.*31. The Great Nebula in Andromeda. R. A. $0^h\ 38^m$; Dec. 40° 46′; this is the only nebula visible to the unaided eye; it is certainly not a mere star cluster, but the spectroscopic evidence of its gaseous character is not so convincing as in some other nebulæ.

*M.*32. Resolvable Nebula; in same field with preceding, with a low power; small but bright.

*H.*VIII.78. R. A. $0^h\ 38{\cdot}1^m$; Dec. 61° 17′; a fine cluster somewhat like the letter W; half way between γ and κ Cassiopeiæ.

*M.*33. Resolvable Nebula. R. A. $1^h\ 28{\cdot}7^m$; Dec. 30° 12′; very large, faint and ill-defined, with spiral structure; a very curious object, fit only for low powers, on account of lack of contrast.

*H.*VI.33 and 34. The Clusters in Perseus. R. A. $2^h\ 14^m$; Dec. 56° 43′; these clusters are often called *the sword-hand of Perseus;* the preceding cluster is the richer of the two, and contains hundreds of stars from the seventh magnitude down to the extreme limit of visibility; near the centre is a beautiful horseshoe or coronet of six stars from the eighth to the eleventh magnitude.

*H.*527. R. A. $2^h\ 16^m$; Dec. 41° 50′; an elongated nebula, presenting the appearance of a flat ring seen almost edgewise; discovered by Miss Herschel in 1783, with a telescope of only 27 inches focal length and power 30; possibly variable.

*H.*VI.25. R. A. $3^h\ 8{\cdot}4^m$. Dec. 46° 55′; a low power shows a very faint large cloud of minute stars (12th to 15th magnitude), beautifully bordered by a brighter foreshortened pentagon.

*H.*VII.61. R. A. $4^h\ 8{\cdot}3^m$; Dec. 51° 1′; a bright cluster; good low power object; the larger stars are arranged in curves.

*H.*IV.26. Planetary Nebula. R. A. $4^h\ 10{\cdot}0^m$; Dec. −12° 58′; bright and round, with an eleventh magnitude star in the centre; does not bear magnification well.

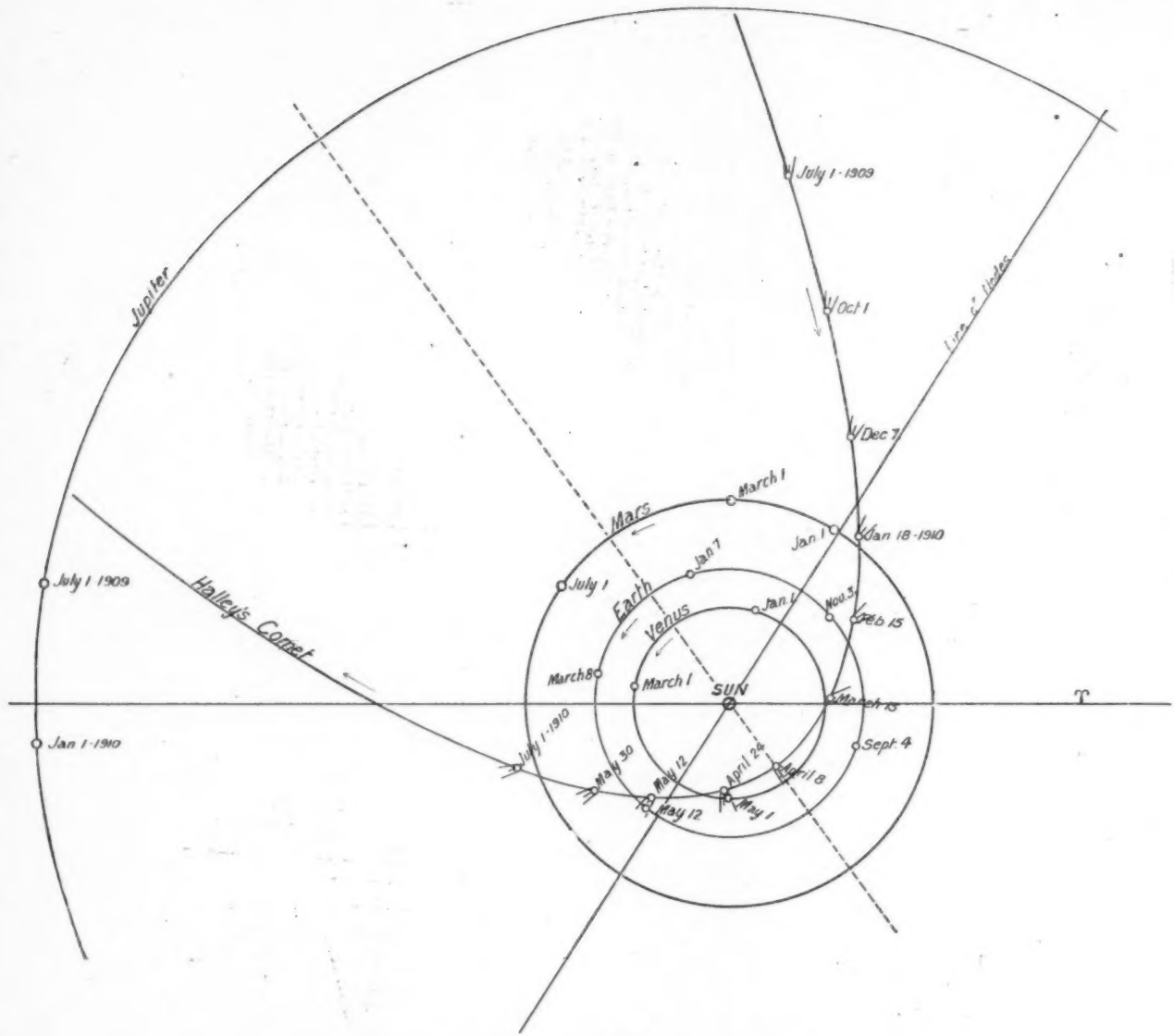


FIG. 1

Path of Halley's Comet, and positions of Venus, the Earth, Mars and Jupiter.

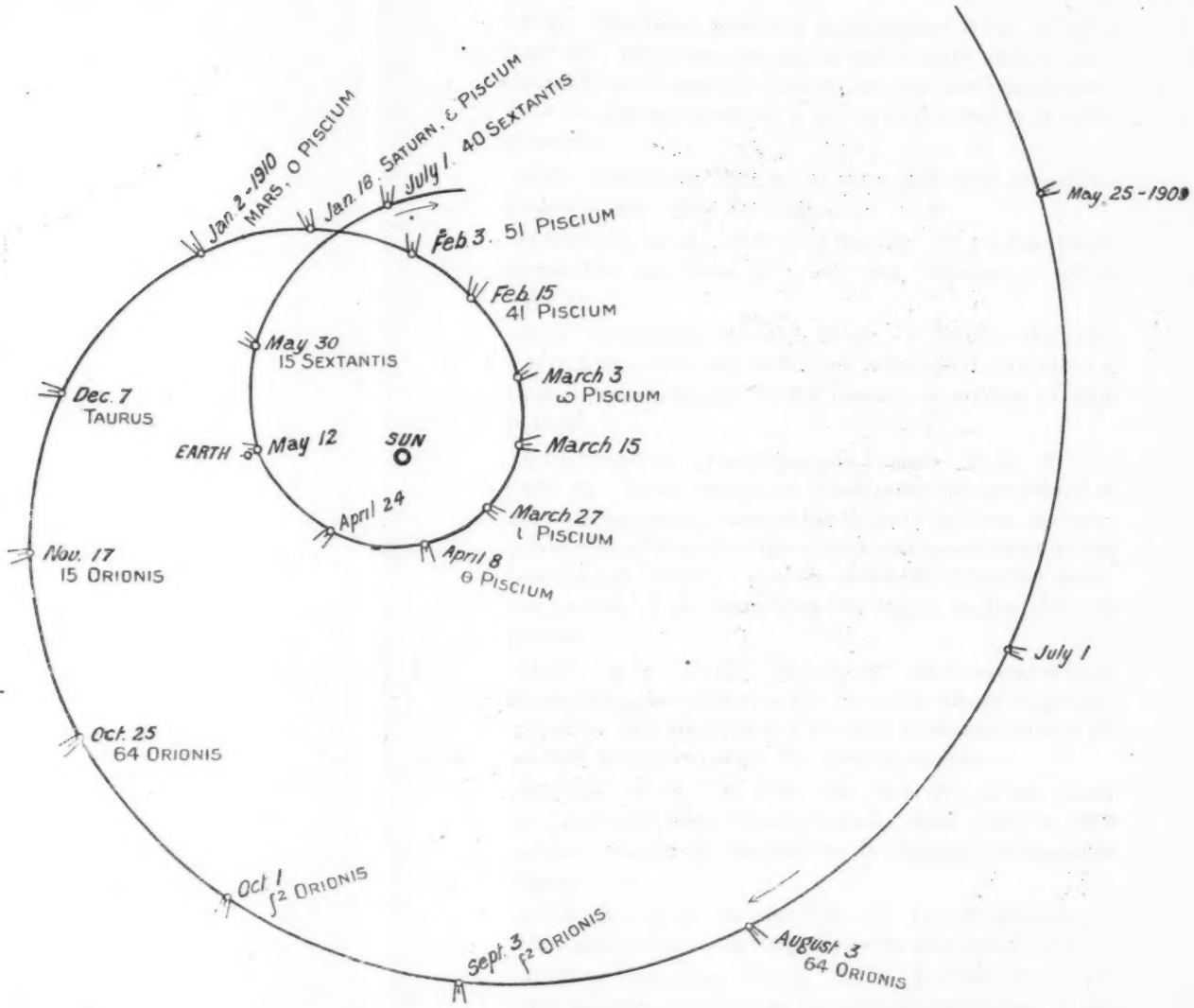


FIG. 2.

Apparent path of Halley's Comet with respect to the Earth and Sun.
(On the dates given, the comet is near the star named after each).

ECLIPSES AND TRANSITS OF THE SATELLITES OF JUPITER

E = eclipse, O = occultation, T = transit, S = shadow, D = disappearance, R = re-appearance, I = ingress, e = egress.

Eastern Standard Time; hours numbering from midnight.

NOVEMBER

d	h	m			d	h	m			d	h	m		
2	4	34	II.	Se	**13**	4	42	I.	ED	**25**	3	42	II.	ED
	5	59	II.	Te	**14**	4	04	I.	Se	**26**	5	59	III.	Se
3	5	26	IV.	Se		4	56	I.	Te	**27**	3	35	II.	Te
5	5	25	I.	SI	**18**	5	41	II.	OR	**28**	5	34	I.	SI
	6	11	I.	TI	**19**	5	44	III.	Te		6	36	I.	TI
6	5	48	I.	OR	**21**	3	41	I.	SI	**29**	2	57	I.	ED
8	5	21	III.	ED		4	38	I.	TI		6	12	I.	OR
9	4	22	II.	SI		5	57	I.	Se	**30**	3	21	I.	Te
	5	59	II.	TI	**22**	4	15	I.	OR					

DECEMBER

d	h	m			d	h	m			d	h	m		
2	6	17	II.	ED	**13**	6	43	I.	ED	**22**	3	05	I.	ED
4	3	33	II.	TI	**14**	3	49	III.	ER		6	29	I.	OR
	4	08	II.	Se		3	49	I.	SI	**23**	2	27	I.	Se
	6	16	II.	Te		4	59	I.	TI		3	38	I.	Te
6	4	50	I.	ED		5	53	III.	OD	**25**	2	30	III.	Te
7	3	02	I.	TI		6	05	I.	Se	**27**	3	19	II.	ED
	4	12	I.	Se	**15**	2	08	IV.	ED	**29**	3	28	II.	Te
	4	20	III.	OR		3	21	IV.	ER		4	58	I.	ED
	5	18	I.	Te		4	34	I.	OR	**30**	2	04	I.	SI
8	2	38	I.	OR	**18**	6	30	II.	SI		3	18	I.	TI
11	3	56	II.	SI	**20**	5	50	II.	OR		4	20	I.	Se
	6	13	II.	TI	**21**	5	08	III.	ED		5	32	I.	Te
	6	41	II.	Se		5	42	I.	SI	**31**	2	52	I.	OR
13	3	10	II.	OR		6	54	I.	TI					

Halley's Comet

Halley's Comet, which was re-discovered by Wolf on September 11, will now soon be coming within reach of moderate telescopes. In addition to its increase in intrinsic brilliance, it is now rapidly approaching the earth, and will continue to do so until about the middle of December, when its distance begins to gradually increase. The relative positions and distances of the earth, Sun and comet for any date may be readily seen from Figure 2, which shows the apparent path of the comet, treating the line joining the earth and Sun as a fixed axis of reference; the affixed star-names show the nearest star at the adjoining dates. The real path of the comet in space is, of course, that shown in Figure 1, the difference being occasioned by the motion of revolution of the earth around the Sun.

AT GREENWICH MEAN NOON

Date 1909	Day of Year	The Sun's Right Ascension	The Sun's Declination	Equation of Time Add to Mean Time	Sidereal Time
		h m s	° ′ ″	m s	h m s
Mon. 1	305	14 24 12·36	S. 14 19 19·2	16 19·28	14 40 31·63
Thur. 4	308	14 36 00·27	15 16 13·3	16 21·02	14 52 21·30
Sun. 7	311	14 47 55·72	16 10 53·4	16 15·25	15 04 10·97
Wed. 10	314	14 59 58·82	17 03 07·9	16 01·81	15 16 00·63
Sat. 13	317	15 12 09·64	17 52 45·4	15 40·66	15 27 50·30
Tues. 16	320	15 24 28.09	18 39 35·0	15 11·89	15 39 39·98
Fri. 19	323	15 36 53·99	19 23 25·4	14 35·66	15 51 29·64
Mon. 22	326	15 49 27·13	20 04 06·2	13 52·18	16 03 19·31
Thur. 25	329	16 02 07·25	20 41 27·6	13 01·73	16 15 08·98
Sun. 28	332	16 14 54·09	21 15 20·9	12 04·57	16 26 58·66

		75th Meridian Time, Hours numbering from Midnight Planetary Phenomena	Minima of Algol	Configuration of Jupiter's Satellites at 5h.
			h m	
	Mon. 1	8h ☿ Greatest Hel. Lat. N.		○124●
	Tues. 2	21h 19m ☌ ♆ ☾, ♆ 4° 11′ S.		2↓1○34
	Wed. 3		13 01	2○413
☾	Thur. 4	16h 37·8m Last Quarter.		41○23
	Fri. 5			43○12
	Sat. 6	15h ♀ Greatest Hel. Lat. S.	9 50	432○●
	Sun. 7			4321○
	Mon. 8			43○12
	Tues. 9	0h 43m ☌ 2↓ ☾, 2↓ 3° 52′ S.; 12·4h ☾ in Apogee.	6 39	41○23
	Wed. 10			42○13
	Thur. 11	17h 27m ☌ ☿ ☾, ☿ 1° 20′ S.		41○23
●	Fri. 12	21h 18.3m New Moon.	3 28	3○412
	Sat. 13			32○4●
	Sun. 14			321○4
	Mon. 15		0 17	3○124
	Tues. 16	23h 27m ☌ ♀ ☾, ♀ 0° 6′ S.		1○234
	Wed. 17	12h 39m ☌ ♅ ☾, ♅ 3° 0′ N.	21 06	2○134
	Thur. 18			1○34●
	Fri. 19			2↓○124
☽	Sat. 20	12h 29·1m First Quarter.	17 55	321○4
	Sun. 21			2↓342○
	Mon. 22	17h 10m ☌ ♂ ☾, ♂ 4° 26′ N.		43○12
	Tues. 23	20h ☌ ♀ ♅, ♀ 2° 33′ S.; 21h 53m ☌ ♄ ☾, ♄ 1° 32′ N.	14 44	41○23
	Wed. 24	19h ☿ in ♑.		42○13
	Thur. 25	8·5h ☾ in Perigee.		41○3●
	Fri. 26		11 33	4○312
○	Sat. 27	3h 51·9m Full Moon; Total eclipse.		4312○
	Sun. 28			324○1
	Mon. 29		8 22	3○42●
	Tues. 30	6h 22m ☌ ♆ ☾, ♆ 4° 14′ S.		1○324

Key to Symbols.—☌ Conjunction; ☍ Opposition; □ Quadrature; ☊ Ascending Node; ☋ Descending Node; ☉ Sun; ☿ Mercury; ♀ Venus; ⊕ Earth; ♂ Mars; 2↓ Jupiter; ♄ Saturn; ♅ Uranus; ♆ Neptune.

AT GREENWICH MEAN NOON

Date 1909	Day of Year	The Sun's Right Ascension	The Sun's Declination	Equation of Time Add to / Sub't from Mean Time	Sidereal Time
		h m s	° ′ ″	m s	h m s
Wed. 1	335	16 27 47·35	S. 21 45 37·7	11 00·98	16 38 48·33
Sat. 4	338	16 40 46·62	22 12 10·4	9 51·39	16 50 38·01
Tues. 7	341	16 53 51·30	22 34 51·7	8 36·38	17 02 27·68
Fri. 10	344	17 07 00·67	22 53 34·7	7 16·69	17 14 17·36
Mon. 13	347	17 20 13·91	23 08 13·8	5 53·12	17 26 07·03
Thur. 16	350	17 33 30·10	23 18 44·3	4 26·61	17 37 56·71
Sun. 19	353	17 46 48·26	23 25 03·0	2 58·12	17 49 46·38
Wed. 22	356	18 00 07·41	23 27 07·6	1 28 62	18 01 36·06
Sat. 25	359	18 13 26·65	23 24 57·6	0 00·92	18 13 25·73
Tues. 28	362	18 26 45 16	23 18 33·8	1 29·75	18 25 15·41
Fri. 31	365	18 40 02·17	23 07 57·8	2 57·08	18 37 05·09

75th Meridian Time, Hours numbering from Midnight

Planetary Phenomena

			Minima of Algol	Configuration of Jupiter's Satellites at 4h.
			h m	
	Wed.	1		2○134
	Thur.	2 12h ♀ Greatest elongation E., 47° 18′.	5 11	12○34
	Fri.	3 1h ♂ ☿ ☉ Superior.		○3124
☾	Sat.	4 11h 12·5m Last Quarter.		24310 4
	Sun.	5 1h ☿ in Aphelion.	2 00	32○14
	Mon.	6 17h 35m ♂ 24 ☾, 24 3° 35′ S.		31○24
	Tues.	7 4·7h ☾ in Apogee.	22 49	24○2●
	Wed.	8		42○13
	Thur.	9		421○3
	Fri.	10	19 38	4○132
	Sat.	11		431○2
●	Sun.	12 14h 58·7m New Moon; Partial Eclipse, invisible in		432○1
	Mon.	13 2h 27m ♂ ☿ ☾, ☿ 0° 3′ S. [Canada.	16 27	431○2
	Tues	14 7h ♂ in ♌; 20h 51m ♂ ♁ ☾, ♁ 3° 4′ N.		43○12
	Wed.	15		24○3●
	Thur.	16 10h 10m ♂ ♀ ☾, ♀ 2° 51′ N.	13 16	21○34
	Fri.	17		○2134
	Sat.	18		13○24
☽	Sun.	19 21h 17·7m First Quarter.	10 05	32○14
	Mon.	20 17h ♄ Stationary; 18h 54m ♂ ♂ ☾, ♂ 5° 0′ N.		31○4●
	Tues.	21 4h 1m ♂ ♄ ☾, ♄ 1° 40′ N.		3○124
	Wed.	22 6h ☉ enters Capricornus, Winter begins.	6 54	2○34●
	Thur.	23 3·8h ☾ in Perigee.		21○43
	Fri.	24		4○123
	Sat.	25 9h ☿ Greatest Hel. Lat. S.	3 43	413○2
○	Sun.	26 16h 29·9m Full Moon.		432○1
	Mon.	27 15h 30m ♂ ♆ ☾, ♆ 4° 9′ S.		431○●
	Tues.	28 3h ♂ ☿ ♁, ☿ 1° 44′ S.	0 32	43○12
	Wed.	29		412○3
	Thur.	30	21 21	24 42○3
	Fri.	31 14h ♂ ♂ ♄, ♂ 3° 12′ N.		4○123

For Jupiter's Satellites, the circle ○ represents the disc of the planet; 24 signifies that the satellite is on the disc; ● signifies that the satellite is behind the disc or in the shadow. Configurations are for an inverting telescope.

Eclipses

I.—A total eclipse of the Moon on the morning of November 27, the beginning visible generally in North and South America and north-eastern Asia, the ending visible generally in North America, north-western South America, eastern and northern Asia and Australia.

CIRCUMSTANCES OF THE ECLIPSE :—

Moon enters penumbra	1.12 a.m.	
Moon enters shadow	2.11 "	
Total eclipse begins	3.14 "	Eastern
Middle of eclipse	3.55 "	Standard
Total eclipse ends	4.36 "	Time
Moon leaves shadow	5.38 "	
Moon leaves penumbra	6.38 "	

First contact of shadow with Moon's limb, 58° East of North
Last " " " " " " 91° West " "
Magnitude of the eclipse = 1·372 (Moon's diameter = 1·0).

II.—A partial eclipse of the Sun, December 12, invisible in Canada, visible in the south polar regions, south-eastern Australia and New Zealand.

CIRCUMSTANCES OF THE ECLIPSE :—

	d	h	m		Longitude °	'		Latitude °	'	
Eclipse begins, Dec.	12	5	56·6	G.M.T.	159	5·9	E.	39	1·1	S.
Greatest eclipse	12	7	44·9	"	85	48·8	E.	65	3·4	S.
Eclipse ends	12	9	32·9	"	17	27·9	W.	54	52·9	S.

Magnitude of greatest eclipse = ·541 (Sun's diameter = 1.0).

Occultations of Stars by the Moon*

Date	Star	Mag.	Time				Position Angle	
			Immersion		Emersion		Immersion	Emersion
			h	m	h	m	°	°
Nov.	22 24 β *Ceti*	6·0	4	35·8	5	43·8	67	232
"	23 26 *Ceti*	6·0	5	7·9	6	7·9	35	260
"	23 33 *Ceti*	6·1	9	15·1	10	26·6	47	242
"	23 *f Piscium*	5·1	13	37·7	14	31·7	42	259
"	20 *A Geminorum*	5·1	17	15·2	18	19·2	103	277
Dec.	2 γ_2 *Leonis*	3·6	16	11·8	17	34·8	104	308
"	26 37 *Geminorum*	5·7	16	41·8	17	34·3	68	309

*Prepared by R. M. Motherwell for use at the Dominion Observatory.